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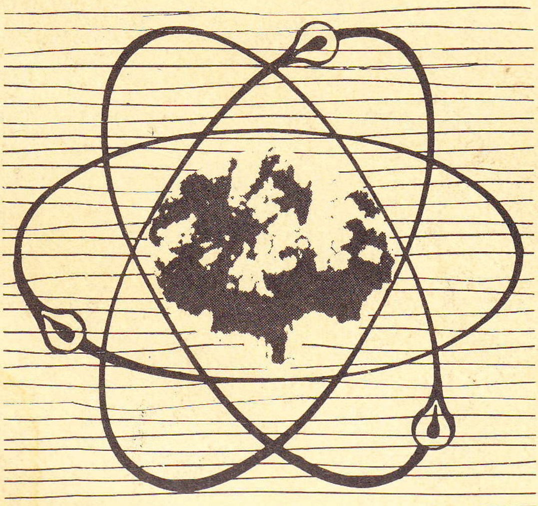

THE CONSEQUENCES OF CHEAP WEAPONS OF MASS DESTRUCTION

ERWIN S. STRAUSS

BASEMENT NUKES

THE CONSEQUENCES OF CHEAP WEAPONS OF MASS DESTRUCTION

Erwin S. Strauss

Loompanics Unlimited
Port Townsend, Washington

DEDICATION

This book is dedicated to the spirit of Samuel Colt, of revolving pistol fame. "All men weren't created equal; Sam Colt made 'em that way." — Western saying.

ACKNOWLEDGEMENTS

The ideas in this book were hammered out in exchanges through the open-forum publication *The Connection* (see Bibliography). The stimulation provided by other Connectors was indispensible in this process. I wish to thank them for their feedback.

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CHAPTER ONE
THE NEW GUNPOWDER

The development of nuclear weapons (fission and fusion) and other weapons of mass destruction (chemical, biological, radiological, etc.), and their increasing accessibility to people and groups with less and less capital, is perhaps the most important development in human history in the past 10,000 years. In considering the consequences of weapons of mass destruction, however, most people tend to take a fairly narrow view. The optimists assert that the emerging genie of destruction can be put back in the bottle, or at least somehow frozen in its present state of being half in and half out of the bottle. The pessimists assert that all is lost, and that the entire human race will soon be annihilated. A few in-between look to a return to conditions of some prior era (the Dark Ages, the Stone Age), or to some favorite Utopia (the poor countries enforcing wealth-sharing on the rich) or dystopia (harsh repression in the name of preventing terrorism).

But history has shown that such simplistic visions of the future rarely come to pass. What usually happens is that some old trends continue, while others recede; meanwhile, some new trends emerge. The result is a complex world, different from any preceding era (though not without similarities) -- a world better than the dystopian visions, but not as attractive as the Utopian ones. As an example, let us consider an event of the (relatively) recent past that is similar to the introduction of weapons of mass destruction -- the introduction of gunpowder into European warfare in the 16th Century. Imagine how a gathering of students of the future might have seen things -- circa 1550:

"My Lords and Learned Gentlemen: we are convened here today to consider the weighty matter of what the future holds in store for the Baronies of Europe and their inhabitants. I think we can all agree that the most portentious development of

recent times has been the advent of Gunpowder Warfare. Although practiced but little as yet, it is clear that if it should break out on any large scale, the entire world as we know it would be destroyed. Mighty fortresses would be as easily overrun as any serf's hut. The best-trained knight in Christendom, with the finest example of the armorer's art, would be as easily cut down as the merest yeoman. In short, all social order would be obliterated. Europe would, at the very least, be thrown back a thousand years into a new Dark Age like that which followed the fall of Rome. Clearly, then, our first priority must be the undertaking of a Solemn and Holy Covenant amongst all the Barons of Europe forever outlawing Gunpowder Warfare, and forbidding the teaching of the art of gunpowder manufacture and use. With such a Covenant in force and the stability of the world assured, we can proceed with such great tasks that face us as the liberation of the Holy Land and the Suppression of Heresy."

But a dissenting voice might be heard in the hall. "Learned Colleague, what you say about the horrors of Gunpowder Warfare is not to be taken lightly. But Heretics and Infidels are not likely to abide by a Covenant amongst the Barons of Europe. Nor are any number of Brigands and Outlaws. And I fear there are even some among the very Barons themselves who would be tempted to dabble in the forbidden arts. Thus it seems to me that any visions of the future that do not include the widespread use of gunpowder may be but idle dreams. However, the future with gunpowder might not be the end of the world. It might not even be a return to the Dark Ages, though not necessarily any less distasteful to us. Life may well go on, and it behooves us to bend our thoughts to the nature and conditions of such life."

But the original speaker would likely not be moved. "Esteemed Brother in Knowledge, no man of Sensitivity and Charity could long survive in such a world as you depict. If such a world came to pass, only the Depraved and Mad would

walk on the face of the Earth. Indeed, even to think long on such matters would be to court madness. Let us therefore pray that such a Calamity is averted by the Grace of God, as surely it will be, and turn our thoughts to more tractible matters."

But of course the dissenter would have been right. The use of gunpowder did become common (as the use of weapons of mass destruction threatens to become). Castles and knights in armor did lose most of their military value (as conventional military forces of today are of little value against terrorists). Baronies did cease to be significant political units as castles and armor became obsolete (as nation-states will be if contemporary military forces are unable to protect against terrorists with weapons of mass destruction). A world did emerge that medieval people would probably consider "chaos" or "unthinkable", the mere contemplation of which might have driven them mad (as some contemporary people might be by the visions of the future we're going to examine here). But life did go on after the introduction of gunpowder to warfare (as it may well in the face of weapons of mass destruction). Life with gunpowder was not a return to the Dark Ages (as life with weapons of mass destruction seems unlikely to be a return to any prior era), though there may have been certain superficial resemblances between the Dark Ages and the Renaissance in regard to the fluidity of social institutions. Concerns that seemed so pressing in 1550, like the suppression of the Reformation (or, today, the redistribution of material wealth and power among nations) gradually lost their appeal as it became increasingly obvious that those goals were militarily infeasible (as the proliferation of weapons of mass destruction would make it difficult to compel a wealthy nation, corporation or individual to share riches without risking a disastrous confrontation).

What form might such a post-proliferation world take? What sorts of economic and political organization might emerge? How could disputes be resolved? In succeeding chapters, we

will explore these prospects. Likely possibilities are a world of small, dispersed communities (the larger and more concentrated settlements are, the more attractive targets they make for blackmailers or those carrying grudges). Close economic ties would be necessary to implement the division of labor that is fundamental to the technology that enables the world to support its present population. But little or no political integration might be feasible, for want of a means of enforcing the rule of the governing authority without risking a suicidal exchange of weapons of mass destruction. Disputes between communities and individuals might be resolved by a variety of means -- perhaps even including a rebirth of duelling. These are startling prospects. However, the more one considers them, the more plausible they may appear.

CHAPTER TWO
HOW TO READ THIS BOOK

"The driving forces of (philosophy) are, contrary to all these solemn airs and assertions (of dedication to truth), not ideal; they are...personal, official, clerical, political, in short, material interests... Governments make of philosophy a means of serving their state interests, and scholars make of it a trade..."

So wrote the German philosopher Arthur Schopenhauer. Such interests remain the driving force not only of philosophy, but of economics, political theory, sociology, and the wide range of disciplines professed by the intellectuals who have multiplied so greatly since Schopenhauer made his observation. When they address some apparently abstract question, a good way to start one's analysis of their thinking is to ask, "*Cui bono?*" Freely translated, ask what the writer's percentage is, how he stands to gain from taking the position he presents.

In the case of politicians, and those employed by them, the application of this approach is not hard to see. But even those who seem the most removed from petty interests, the most dedicated to the search for the pure, lambent flame of Truth for its own sake, tend to have more mundane irons in the fire as well. For example, even ivory-tower academics have careers to consider. At first, the scholar must win the favor of those more senior to gain a position. Then there are further prizes to be won -- a tenured chair, editorship of an influential journal, chairmanship of an important committee, and so on. Finally, the brightest of the next generation of scholars must be wooed to carry on one's school of thought. At every turn, there are competitors vying for the same glittering prizes, using opposing ideas as their weapons.

This is not to disparage unduly the work of such people. Many of the greatest ideas in human history have been

advanced, refined and established in the crucible of such adversary processes. The weakness of the intellectual adversary system is not that it leads to incorrect answers -- over generations of scholars, the correct answer on a given point tends to prevail. However, the questions that are considered at all tend to be restricted to those that have a bearing on the current interests of the parties involved. For example, consider the question to which this book is addressed -- the consequences of cheap weapons of mass destruction. Many people have interests that can be advanced by attacking this question. For instance, many people advocate the abolition of nuclear power plants. Their motivations are beyond the scope of the present work, but their ends can be advanced by asserting that, if nuclear power continues, fissionable material will fall into the hands of terrorists, and that this will result in the collapse of civilization. The proponents of nuclear power counter with talk of controls and safeguards. But what of the possibility that terrorists might get weapons of mass destruction by some other means? I have raised this question in forums where this subject was being considered, but found little interest in pursuing such a line of thought. Both sides take the position that this would be disastrous, and offer unsupported hopes that it will never happen. Neither side of this question tends to support or refute the desireability of nuclear power, so interest in discussing the point is slight.

International affairs in another arena in which a limited approach to our problem is found useful. Proponents of disarmament advance their cause by asserting that universal annihilation is the only possible outcome as long as weapons of mass destruction exist. Proponents of increased military activity, such as the authors of the recent best-seller THE THIRD WORLD WAR, assert that a nuclear war could be won with only a very limited nuclear exchange -- hardly more destructive than many World War II air raids. What of the possibility of major, but survivable, disruption of human life

and patterns of society? Once again, the current interests of these advocates aren't advanced by considering such questions. For the disarmament faction, admitting the survivability of nuclear exchanges weakens their case. For the military faction, admitting that the current way of life in their countries can't survive a nuclear exchange weakens their case. So there is no interest in discussing such a proposition.

In fact, as everyone from fire-and-brimstone preachers to cancer-cure promoters knows well, the more something is feared (Hell, or cancer, or nuclear war), the less likely it is that something touted to ward it off will be examined critically. Thus the promoters of a wide range of social nostrums -- from a world government to religious revival, from no-growth to militarism -- have an inherent interest in painting all uses of weapons of mass destruction as indistinguishable catastrophes. Thus their professional biases lead away from a thoughtful consideration of the consequences of cheap weapons of mass destruction.

Dramatically speaking, this is the time for me to enter, stage right, as the White Knight of Truth, free of all such biases. But of course I, too, have a particular point of view that should be kept in mind when reading this book. I enjoy exploring the overlooked alternative, the unusual and off-trail possibility, especially if it is unconventional enough to titillate or shock. As a result, the conventional alternatives tend to get short shrift. This can be rationalized on the grounds that other people have explored the conventional alternatives. To mitigate this bias, I have prepared a bibliography to provide access to these alternatives. It is not my intention to present my view of a possible future as at all inevitable. Perhaps some perfect defense against weapons of mass destruction will be invented (although I can see no prospect of that at this date). Or perhaps someone will push the red button and there will be a general nuclear war. I have no great insight into the minds of the world's political leaders, and have nothing special to add to

the debate over whether such a war will occur. Some people's reaction to this book may be to put forward their own, alternative scenarios. But this will not refute my arguments. To do that will require showing not merely that another alternative is possible, but that my alternative is so improbable as not to be worth considering. If I become overenthusiastic in arguing the plausibility of my scenario, keep in mind that the point is not whether that scenario is inevitable, but whether it is reasonably possible.

Speaking of anticipating whether there will be a general war, it is important to distinguish between forecasts of general trends, and predictions of specific events. This is comparable to the difference between forecasting areas and periods of time in which tornados are likely, and predicting the exact time and place that individual funnel clouds will touch down. The former is possible to a reasonable degree of accuracy. The latter would be far more useful, but depends on factors that are, for all practical purposes, random. In human affairs, the desire for such detailed predictions has been so strong throughout history that there have always been those prepared to offer them anyway. From the first shaman to cast the bones around the campfire to foretell the next day's hunt, through the court astrologers of ancient and medieval times, to the newspaper columnists and think-tankers of today, these pundits have always found a ready market. In fact, their pronouncements have always amounted to about the same thing: guesses based on common sense, heavily diluted with what the paying customer wants to hear, embedded in a lot of mumbo-jumbo to give it an ambiance of certainty.

This book amounts to a nuclear tornado watch. I will attempt to outline the kinds of people likely to use weapons of mass destruction, and the circumstances under which they are likely to be used, assuming that nothing drastic (like a general nuclear war) changes things. If some of the thousands or millions of people who gain access to such weapons don't use

them, perhaps others will. If they are not used in one place at one time, perhaps they will be used somewhere else at another time. It would be nice to be able to say just when and where weapons of mass destruction will be used, but I'm afraid I can't offer much help in that regard.

In line with avoiding punditry, I intend to be deliberately vague about the timing of the developments I discuss. Cheap weapons of mass destruction could start to emerge at almost any time -- who knows what's going on in clandestine laboratories and workshops at this very moment? In general, though, I tend to think in terms of the next century. If the trends I project aren't well underway when the better part of the 21st Century is history, it would be reasonable to say that I have some rethinking to do. As I said, it would be nice to be more precise, but I don't see any way to be that.

Another point on which it may be easy to misunderstand this book is the desirability of the developments projected. As one gets involved in a particular scenario, one tends to develop a certain affection for it as one's brainchild. If I get over-enthusiastic in defending the viability of the way of life resulting, don't be misled. My own preference in life-style involves frequent short trips to different cities. I enjoy the vigor and variety of the various cities of the world, and I return refreshed from my travels. In the world I will be examining, society will tend to be organized in small, homogeneous communities, to which outsiders will generally only be admitted if they have definite business. It is hard to tell exactly what such a future society would be like, but it is certainly not obvious that the choice between that society and the present society would be easy (not that there will be such a choice, of course). And, whatever the result, the transition from here to there seems likely to be rather horrific. Or, as the Chinese might put it, "interesting" (as in the Chinese curse, "May you live in interesting times"). By the same token, my arguments about the difficulty of suppressing weapons of mass destruction

shouldn't be taken as categorical denunciations of efforts directed at control of those weapons. Such measures can serve to buy time, both to enjoy the luxuries of the present era, and to prepare for the future. However, these advantages are wasted if those steps are regarded as not merely slowing the advent of widespread weapons of mass destruction, but of avoiding it altogether. Such a head-in-the-sand attitude will only make things worse when the crisis comes.

Finally, don't forget that the scope of this book precludes giving the most complete, detailed arguments on each point covered. I'll try to present a rudimentary case here. Many of these points have been discussed in greater detail in the publication *The Connection* (see Bibliography), to which those interested are referred. I expect to continue to deal with specific objections in that forum and elsewhere, and I welcome new participants in such exchanges. As I said above, a principal problem has been getting people to take an interest in addressing these matters at all.

CHAPTER THREE
THE TECHNOLOGY

Before spending a lot of time delineating the consequences of cheap weapons of mass destruction, it is worth a certain effort to dispel doubts people might have about the likelihood of such weapons becoming widely available. The purpose of this chapter is not to provide a cookbook for making such weapons. A lot of the practical aspects of making and delivering them to a target would require much more information about the details than a book this size could hold. In fact, some of the details I cover here may be wrong. I have made no attempt to "kitchen test" them. The point of this exercise is to show that a wealth of information is generally available that indicates the way to go, and that there are few obvious obstacles that present any fundamental difficulty. If one approach to weapons of mass destruction doesn't work, then there are many others to take its place. The likelihood that all approaches will fail seems sufficiently limited to make it worth our while to explore the consequences of success in some detail.

Keep also in mind that the precise state of technology now is not so much the issue as is the state of technology in decades to come. Consider the progress that has been made over the last few decades in many of the things that are central to the weapons-production approaches covered below -- computers, lasers, magnets, etc. Lasers didn't exist at all twenty years ago; now any scientific supply house has them for a few hundred to a few thousand dollars. In the same period, computers have gone from being rooms full of equipment to being small units for the home, with comparable computing power. And so on.

Another point to consider is not taking the term "basement nukes" too literally. Much of the technology discussed below would be difficult if not impossible to carry out in a typical residential basement. So far as is publicly known, all of the

nations having nuclear weapons have produced their own for their own use (though there are rumors that Libya and Pakistan may be cooperating on a joint program). As smaller nations move into the business, and then sub-national groups (terrorists, private businesses, etc.), this pattern will probably continue for a while. However, there eventually comes a threshhold. The general rule in economics is that, the cheaper the price of something is, the more people there will be interested in buying it. There has always been a strong demand in the world for the most powerful weapons available at any given time, and I see no reason to expect weapons of mass destruction to be much different. But it's also generally true (and the specifics discussed below will bear that out) that the more units of a given product that are turned out, the lower the cost per unit will be. This is because specialized machinery and skilled personnel can be kept busy continuously, rather than becoming idle when the requirements for weapons of the originator of the effort have been satisfied.

However, there's a catch here -- the problem of coordination. If these economies of scale are to be realized, several things have to be accomplished. First, an amount of capital corresponding to what the eventual customers are willing to pay for the product must be assembled. Then the appropriate facilities and personnel must be assembled, and the weapons produced. Finally, the weapons must be placed in the hands of the customer, and the money collected to repay the capital involved. But this is no major hurdle. There are large numbers of people in the world today who are experienced at performing these sorts of functions in the face of active opposition by the combined governments of the world. Generically, the activities of these people are known as the "black market". Because the U.S. imposes relatively few restrictions on trade, most Americans are relatively unfamiliar with its extent. Except for those over 50 years old who remember the rationing of World War II, the aspect of the black market that they are most

familiar with is the drug traffic. But this serves as a good example of what's involved in such operations -- the remote areas where raw materials are produced; the clandestine processing laboratories; the long smuggling routes to the consuming areas of the world; the intricate distribution chain that places the product in the hands of the consumer. At each stage of the operation, the services of skilled people are employed, selecting the site for a clandestine base of operations, knowing which officials should be bribed, and so on. But on a worldwide scale, the activities aren't limited to such things as drugs. Precious metals move into India, household appliances move into Southeast Asia, guns move almost anywhere -- the list is virtually endless. The manufacture and distribution of the weapons described below would present no serious problem.

Among law-enforcement agencies, the interdiction of 10% of black market traffic is considered a good rate of success. This provides a steady stream of defendants to parade before the media to show that the police are earning their pay. It is also enough to oblige the remaining 90% of the traffic to stay in the shadows, and do its dealing by night rather than in broad daylight. This allows the respectable citizens to go about their business without running directly into black market activities, and thus allows them to convince themselves that their own personal black market contact is a rare exception, and that basically the law is being observed. For the governments involved, this is the most urgent issue involved in dealing with the black market. Nothing can so quickly undermine the authority of a government than for the average citizen to see its decrees openly flouted by large numbers of people. Even animal societies don't last long if the dominant animal is seen to be mocked with impunity. Some officials might like to see the contraband traffic stopped (though others have a strong interest in seeing the activity flourish, as a source of bribe income), but such considerations are less urgent than more

fundamental issues.

Once the black market gets into the business, it may well be possible to purchase a complete bomb, or to purchase prefinished parts which might well be assembleable into bombs in an ordinary basement. This will be the true era of the "basement nuke".

Before moving into the details, let me make a few final points. The information below has been obtained from generally-available sources. No classified information is involved. More than that, it is not gleaned from some obscure sources that are available only to those who know where to look. All of the information is taken from popular publications that have sold tens of thousands of copies. Much of the information is from John McPhee's THE CURVE OF BINDING ENERGY, which has sold millions of copies. Thus no new information is being placed in the hands of aspiring terrorists. This book is directed at ordinary people who have been lulled into complacency by talk that producing these sorts of weapons would require an effort comparable to the multi-billion-dollar Manhattan Project that produced the atom bomb in World War II. General Delmar Crowson of the US Air Force, who headed up much early work on nuclear weapons, estimates that one to two dozen people would be needed today to mount a nuclear weapons effort. We'll go into the reasons for that drastic reduction in effort below.

And, lastly, before getting bogged down in a variety of technical details, let's look at the broad sweep of human history. One of the dominant trends in that history has been the gaining of ever-increasing control of the environment. The means by which individuals, from kings and presidents to ordinary people, control their surroundings have steadily increased, even in periods that are thought to represent regressions in history, such as the Dark Ages. A graph showing the amount of energy disposed of by the average person is exponential in form over time -- rising dramatically in

recent years. The weapons described below are logical extensions of that trend. Though of course this doesn't prove the inevitability of their spread, it strongly suggests that those weapons are not some flukey aberrations, such that if they can be held off for a little while, the threat will go away. Rather, they reflect fundamental trends, which indicates that dealing with them is likely to be a perennial problem, requiring substantial adjustments in the way society operates.

Now on to discuss the various approaches to cheap weapons of mass destruction in detail.

Fissionable Materials

A convenient place to begin a survey of weapons of mass destruction is with fissionable, or fissile, material. This is the material that forms the heart of the most familiar weapon of mass destruction, the atom bomb. In addition, this material alone can be a powerful chemical or radiological weapon. There are two forms of fissionable material that are the most important from a weapons standpoint. These are uranium of the type with an atomic weight of 235, or U235, and plutonium. Each has its own advantages and disadvantages.

Plutonium is the material favored by professional bomb designers. Unlike U235 (which is virtually identical chemically to its heavier relative U238), plutonium is a distinct chemical substance. Therefore, methods of chemistry can be used to separate and refine plutonium for use in an atom bomb. Plutonium is especially favored for use as the igniter in hydrogen bombs, because it releases its explosive energy faster than U235, and thus more of that energy has a chance to work at setting off the H-bomb before the force of the explosion scatters the parts of the bomb. Less plutonium (chemical symbol: Pu) is needed to make a bomb than is U235 -- only about four and a half pounds.

However, plutonium also has its disadvantages. Because it is unstable -- that is, it tends to disintegrate spontaneously --

most of the plutonium created in nature has long since broken down into more common elements. Therefore, the bomb maker has to create plutonium from scratch, an extra step in the process. Also, plutonium is highly poisonous from a purely chemical point of view, even disregarding its radioactivity. A pellet of plutonium whose diameter is half the thickness of a dime is enough to kill you, if it's in a liquid or vapor form (which it is during much of the processing involved in bomb making). That same amount divided among a thousand people would expose them to a high risk of getting cancer, due to the radioactivity.

On the other hand, U235 occurs naturally in the world. In natural uranium, about 7 atoms out of every 1,000 are U235. Most of the rest are the heavier, non-fissionable U238. For use in a bomb, the U235 must be separated from the U238. This is quite difficult, since the two are essentially identical chemically. Methods must be used that are based on the fact that an atom of U235 weighs only 235/238ths as much as an atom of U238. since this difference in weight is so small, the methods have to be very tedious and painstaking. In addition, more U235 is required for a bomb than is plutonium -- about eleven pounds.

The most direct approach to obtaining fissionable materials is simply to appropriate those that have already been created in connection with the existing atomic weapons and nuclear power programs. This approach has been extensively discussed elsewhere, especially in McPhee's book mentioned above, and so I won't spend much time on it here. To some extent, the safeguards on fissionable material have probably been tightened since that book was written, perhaps because of the book itself. The future prospects for such diversion of fissionable material are hard to assess, and shade off into the realms of punditry. Will existing nuclear power plants continue to operate? Will new plants be built? Will plutonium be used as a fuel? Will a treaty be entered into that calls for the dismantling of the nuclear weapons industry? And so on. I have no special insight into those matters, and I'm not particularly interested in trying to guess. I'll concentrate on getting fissionables directly from natural sources.

Uranium

The first step in getting U235 is to get raw uranium, with U235 and U238 mixed in the proportions given above. There are many natural deposits of uranium in the world, a disproportionate number of them in North America. Many of these deposits are in remote, rugged reaches of the Rocky Mountains. Even richer deposits are found throughout the Appalachian region. For environmental and other reasons, these deposits are not mined commercially, leaving them for the exclusive use of clandestine miners. The deposits are far too numerous and scattered to guard closely. These deposits are commonly in the form of the oxides of uranium, the most common being $U^3 0^8$ -- three atoms of uranium bound to eight atoms of oxygen.

The first step is to obtain concentrated ore. Assuming that only about half of the U235 in the ore will be ultimately isolated, ore containing about 21 pounds of U235 must be handled. This corresponds to about 3000 pounds of uranium metal. Appalachian ores typically contain around 12 pounds of uranium per ton of ore. This works out to 250 tons of ore. At a typical earth density of 1.5 tons per cubic yard, this is a volume of around 170 cubic meters -- a cube of materials between five and six yards on a side.

This volume can be reduced greatly at the mine site. The principal technique for removing dross from ore is crushing and flotation, a straightforward mechanical process. This can be supplemented by acid and alkaline leaching, washing and filtering, solvent extraction and ion exchange. The uranium-bearing minerals themselves contain from 10% to 85% uranium, with most containing 30% or more uranium. If the concentration of uranium can be raised to 15%, ten tons of

concentrate would contain the needed 3000 pounds of metal. At a density of 2.5 tons per cubic yard, this would come to a volume of four cubic yards -- a cube less than two yards on a side. This is the amount of material that would actually have to be treated by the more sophisticated chemical techniques below.

The UF^4 must now be converted to uranium metal. Place the U^3O^8 on a vibrating tray in a laboratory furnace of the type that can be bought in any scientific supply house, and then heat some hydroflouric acid in a stoppered flask. Hydroflouric acid can also be obtained from a scientific supply house. It is commonly used to etch glass (it is sold in plastic bottles; in the old days, they had to used wax-lined glass), so its purchase shouldn't arouse suspicion. Through a tube in the top of the hydroflouric acid flask, the acid passes into the U^3O^8 as a gas. When the furnace is heated to 600° Celsius (about 1,100° Fahrenheit), water and UF^4 are formed.

If the uranium is obtained by diversion from a nuclear industry, it will likely be in the form of UF^6 -- uranium hexaflouride, one atom of uranium bound to six atoms of flourine. This is a convenient form for performing various commercial operations. To convert this into uranium metal, mix it with carbon tetrachloride in an evacuated nickel container -- four parts of the carbon tetrachloride to one part of the UF^6. Heat it (perhaps on a stove) to 150° Celsius (about 300° Fahrenheit). The carbon tetrachloride and the UF^6 will react to form uranium tetraflouride (UF^4) and flourinated carbon chloride. The UF^4 will be a loose cake of solid material, which should be washed with a weak acid (perhaps white vinegar) or alcohol.

Six parts of UF^4 are mixed with one part of powdered magnesium in a graphite crucible. Potassium chlorate is added to produce additional heat during the reaction. The crucible is

then placed in a strong steel container, along with electrical ignition wire -- like the wire in a toaster or electric heater. This is used to get the material up to a temperature of 600° Celsius (1,100° Fahrenheit). At this point, the UF^4 and the magnesium ignite, turning into magnesium flouride and uranium metal. When the mixture has cooled to about the boiling point of water, spray water on it to bring it down to room temperature. A small hemisphere of uranium metal is left in the crucible.

At this point, there is a choice. You can separate out the U235 to make a bomb, or you can convert the entire quantity of uranium (mostly U238) into plutonium. We'll leave the latter to the discussion of plutonium, below. For now, let's concentrate on separating the 7 parts per thousand of U235 from the rest of the uranium. The original separation method, used by the Manhattan Project at Oak Ridge, Tennessee, in World War II, is called gaseous diffusion. The uranium is converted into UF^6 using hydroflouric acid. UF^6 vaporizes readily. Certain membranes can be constructed which allow UF^6 to pass through, but only slowly. Because it is slightly lighter, the UF^6 molecules with U235 pass through a little faster than those with U238 -- but only very slightly faster. Each time the UF^6 is allowed to pass through the membrane, the gas that has passed through has a little more U235 than before, and the gas left behind has a little less. The gas must be passed through the membrane many times to attain the 97% U235, 3% U238, that is needed for a bomb. In practice, this means building many large gas chambers, with many membranes, and using huge pumps to force the gas through under pressure. Such a separation plant covers hundreds of acres, and requires a large fraction of the power produced by the enormous Tennessee Valley Authority (which is why the Manhattan Project plant was built in Tennessee). Such a plant would be virtually impossible to build and operate clandestinely. However, this is only the most primitive way of doing

the separation, and is generally regarded as obsolete in the nuclear community (though the existing plants, with their large investments in gaseous diffusion, will continue to operate for quite a while in the original nuclear countries). With the rising price of the energy needed to run them, the U235 produced by those plants will have a hard time competing economically on the world market.

2 The next technique to emerge for separation was the centrifuge. The UF^6 is whirled around at high speeds. This effectively multiplies the force of gravity. The UF^6 molecules containing U238, being heavier than those containing U235, tend to move to the bottom of the containers being whirled, away from the center of rotation. Thus the UF^6 at the bottom has slightly less U235 than the whole sample, and the UF^6 at the top has slightly more. Again, this process must be repeated many times over to achieve the desired 97% concentration of U235. Although it still requires large amounts of capital investment, electric power and space, these requirements are considerably smaller than those for gaseous diffusion plants. Furthermore, the various centrifuges involved can be spread around different locations more easily, and thus concealed. West Germany has sold the technology for these centrifuges to Latin American countries, so it will probably be pretty widespread before long.

3 But we are still dealing with relatively expensive, large-scale techniques. Others have been developed. For example, when an atom of any substance is given an electric charge and sent near a magnet, its path is bent by the magnet. U235, being lighter than U238, is bent more. However, the amount of bending also depends on how fast the atom is going -- a slow U238 atom and a fast U235 atom will have their paths bent by the same amount, and end up in the same place. At a given temperature, most atoms have about the same speed. However, there is some variation in speed; and, since the difference in weight is so small, this variation in speed is a

problem. Once again, the process will only divide the uranium into a part that has a little more U235 than average, and a part that has a little less. The process must be repeated many times to purify the U235. The magnets needed to make this process practical have to be very strong. The only way to get such magnets is to make electromagnets by winding coils of wire made of tin and niobium (other alloys will do, but this is the preferred material), and cooling them to nearly absolute zero (273° Celsius, or 459 ° below zero Fahrenheit) by putting them in liquid helium. This is an example of a technology that was recently found only in the most advanced laboratories, but which is now available even to secondary schools. Israel and South Africa are rumored to be in the forefront of the use of this technique to separate U235.

These two nations are also said to be leading in the development of another separation technique. This is similar to the magnet technique above, except that the charged atoms of uranium have their paths bent by being zapped with a laser. Once again, the lighter U235 atoms are pushed further out of their way than the heavier U238. And, once again, many passes through the laser are needed to purify the U235. In the April, 1979, issue of *Analog Science Fact and Science Fiction Magazine*, George Harper published a sardonic article. It purported to be an easy recipe for making a fission bomb, and then proceeded to make the process sound as difficult as possible. From this attitude, it's reasonable to conclude that his attitude towards the technology is very conservative -- if he says something is possible, it probably is, and is likely easier than he says. He says that lasers that are "readily available" (which, from the context of the article, seems to mean available through scientific supply houses) can process 20 pounds of uranium a day, with a separation efficiency of 12.5%. From this, he quotes a period of four years to produce 36 pounds of 97% pure U235, starting from hijacked nuclear fuel, which is 3% U235, passing the material through the laser nine times.

Starting from natural uranium, an extra pass or two will be needed, totalling eleven passes. However, though the ridiculously inefficient bombs he describes may require 36 pounds of U235, the bombs we will discuss here need only a third of that. This corresponds to a time of about 20 months -- using a single laser. However, lasers are not women -- nine women can't produce a baby in one month, but 20 lasers can produce a bomb (or the makings of one) in one month. Or four lasers can do it in five months, ten lasers in two months, and so on.

Plutonium

As I have been saying, however, plutonium is the preferred material for bombs. The way it is produced commercially involves a nuclear reactor. As the 3% of the uranium in the reactor fuel fissions -- that is, splits up into smaller atoms and gives off loose neutrons -- some of the neutrons produced are absorbed by the 97% of the uranium that is U238. Through several intermediate stages, the U238 becomes plutonium. This is the basis for the highly-publicized "breeder reactor". However, while such a reactor is needed to achieve high levels of economic efficiency in plutonium production, any reactor will do. There are a large number of small research reactors around the world, many in inconspicuous small buildings in the middle of cities. Their construction is quite different from that of power reactors, so such problems as meltdown of the core ("the China syndrome") are not considerations. A clandestine reactor of this sort is quite plausible.

Another way to produce plutonium is the same in principle, but speeded up. A bomb made with U235 (or plutonium) can be exploded in a blanket of U238. In a fraction of a second, a major part of the U238 becomes plutonium. If the bomb is buried, the plutonium will not be too widely scattered.

Unless some weapons-grade plutonium is being hijacked, the plutonium produced by the above methods will be mixed with leftover U238. Getting U238 out of plutonium is much easier

than getting it out of U235, because plutonium is different chemically from U238. First, dissolve the plutonium/U238 mixture in nitric acid. Then add oxalic acid, to form plutonium oxalate. The uranium will stay in solution -- it doesn't react with oxalic acid. The plutonium oxalate, however, will precipitate out of the solution as crystals, which can be collected by filtering the solution. If you're hijacking plutonium, it will likely already be in the plutonium nitrate form, so you just add the oxalic acid and filter. Heating the plutonium oxalate will drive off any leftover water. The dry, or anhydrous, plutonium oxalate is then heated to 500° Celsius (932° Fahrenheit), and hydroflouric acid is passed over it, using the heated bottle of the acid with a tube in the stopper, as described above for U^3O^8 refining. The plutonium oxalate becomes plutonium flouride. Next, line a crucible with magnesium oxide, to resist high temperatures. For this, the magnesium oxide is mixed with water, and a paste is formed which can be worked like clay. The same technique will be used later to form molds for the metal actually used in a bomb. About a pound of plutonium should be worked with at a time, no more. This is to be sure that you don't wind up with a critical mass that explodes in your face (the explosion would be pretty feeble by weapons standards, but more than enough to take care of you). And don't forget that plutonium is a deadly poison. All of this work should be done in what is called a "glove box". This is a box with a glass top, and a pair of heavy-duty rubber gloves molded into the side. When the plutonium is inside, the box can be sealed, and all of the work can be done by putting your hands in the gloves.

Into the magnesium oxide crucible, put about a pound of plutonium, a third of a pound of metallic calcium, and a tenth of a pound of crystalline iodine. The air in the glove box should have been replaced, before sealing it, with argon, a heavy gas that will not react with the stuff in the crucible. Using an induction furnace, heat the mixture to 750° Celsius (1,400°

Fahrenheit). A chemical reaction will then begin that will heat the crucible up to 1,600° Celsius (3,000° Fahrenheit). Considerable pressure will develop. Within the glove box, you will need to have a strong steel pressure vessel. With the induction furnace off, the mixture should cool to about 800° Celsius (1,500° Fahrenheit). It can now be taken out of the pressure vessel, and allowed to cool to room temperature. Use nitric acid to wash off the remaining iodine, and the calcium flouride produced in the reaction. This leaves a lump of pure plutonium.

As a simpler alternative, plutonium oxalate can simply be heated to a temperature of 1,000° Celsius (1,830° Fahrenheit) to produce plutonium oxide. Like U^3O^8 (as long as the U is U235), plutonium oxide can be used to make a crude, inefficient bomb.

Tritium and Deuterium

Before concluding this section on fissionable materials, there are a couple of other substances we should discuss. One of them is tritium. Just as U235 is a radioactive form of uranium, tritium is a radioactive form of hydrogen. It, too, is outnumbered in natural hydrogen by the ordinary kind -- so much so that separating it out of natural water isn't practical. As with U235, it differs from the common hydrogen only by its weight. Tritium, however, weighs fully three times what ordinary hydrogen weighs, so that, once you get a reasonable concentration, it is much easier to separate out. Tritium is useful for atom bombs, and even more useful in hydrogen bombs. It was discovered in 1934 when a cyclotron was used to accelerate deuterium, and make it strike a deuterium target. Such cyclotrons have been built by high school students for two decades or so. Whether the yield is large enough to make this a practical method of producing tritium is another question.

There's another form of hydrogen that is useful in atom bombs, and indispensible in hydrogen bombs. This is called

deuterium, and weighs twice what ordinary hydrogen weighs, falling between ordinary hydrogen and tritium in weight. It is not radioactive, so a substantial quantity of it can be found in ordinary water. About one atom of hydrogen in 5,000 is deuterium. This is separated out of the water in much the same way as U235 is separated out of ordinary uranium, except that since deuterium is fully twice as heavy as ordinary hydrogen, far fewer passes through the separation process are needed. Basically, the separation is done by passing a direct current through water, to which things have been added to increase the conductivity of the water. The hydrogen that bubbles off the cathode of the electrolysis cell is richer in ordinary hydrogen than the original water, and the water left behind is richer in deuterium. Membranes are usually added within the water to enhance the ability of ordinary hydrogen to move faster to the cathode.

Tritium is produced in essentially the same way as plutonium -- by bombardment with neutrons. Commercially, this is done by placing lithium in a nuclear reactor, and exposing it to the neutrons produced by the reactor. As with uranium and hydrogen, there are two forms of lithium that differ by weight. Most of the lithium has an atomic weight of 7, but it is the 7.4% that has the atomic weight of 6 that gets turned into tritium. However, there is no need toworry about separation -- just expose enough lithium to get the amount of tritium you need. The lithium of weight 7 (Li7) can be separated chemically from the tritium at the end of the process, along with any of the lithium of weight 6 (Li6) that didn't get converted into tritium. The process also produces ordinary hydrogen, but this can be separated from the tritium the same way it is separated from deuterium. In practice, tritium is used in conjunction with deuterium in nuclear weapons, so the separation doesn't have to be perfect. Commercially, tritium is used to make such things as luminous watch dials. The radiation of tritium is much easier to stop than that of the

radium that used to be used -- the glass face of the watch itself does fine as a shield. For applications requiring a small quantity of tritium (such as the neutron gun discussed below), the luminous material in watches can be collected to do the job. Tritium can also be produced by exposing lithium to an atomic explosion.

The method of producing plutonium and lithium in a bomb explosion should be carefully noted. By this means, as long as there's plenty of U238 and lithium, each bomb made can breed many other bombs, like rabbits. Low-yield atom bombs can be set off underground in places like salt domes with minimal chance of detection. For extra security, the detonator could be attached to a seismograph, to explode the bomb to coincide with a natural earthquake. The net resultant output of other seismographs in the area might be slightly unusual, but it would be hard for monitors watching them to tell what you were up to -- particularly since they probably couldn't even detect the bomb alone unless they were very close.

Atom Bombs

We come now to the basic weapon of mass destruction, the atom bomb. The principle is familiar to everyone who has had a high-school physics course. Certain heavy atoms (e.g., those of U235 and plutonium) will break up if the nucleus of that atom is struck by a neutron. In the process of breaking up, a considerable amount of energy is released. This energy is represented by the speed at which the various pieces into which the atom splits fly off, and by radiation. Some of the pieces are neutrons. If, for example, two of these neutrons each strike other atoms, inducing them to split in turn, they produce neutrons that strike four atoms. These then cause eight atoms to split, and so on. Very quickly, a large part of the atoms in a piece of the material have split and given up their energy. The result is a nuclear chain reaction -- in a bomb, the result is an explosion.

However, if you remember high school chemistry, most of an atom is empty space. The weight (mass) is concentrated in a small nucleus. Thus there is a good chance that the neutrons produced when an atom splits will go right out of the material, missing the other atoms altogether. Several things need to be done to overcome this tendency if a bomb is to work well. The first thing is to assemble as much of the fissionable material as possible, in a shape as nearly spherical as possible. In this way, the neutrons are forced to run as large as possible a gauntlet of other atoms, increasing the chances that they will hit one. The amount of material needed is what is called the "critical mass". But, actually, there isn't one critical mass. The amount of material required depends on a number of other factors, as we'll see below.

Another problem is the way in which the critical mass is assembled. If you held half the critical mass in each of your hands, in the shape of a hemisphere, and brought them together as hard and fast as you could, you would get an explosion all right. It would kill you, but it would be negligible by nuclear standards. As the two halves approached each other, the neutrons escaping from each half would start to run into atoms in the other half. The chain reaction would begin, and the energy released by the first atoms to split would blow the rest of the material apart, before the atoms in it could get hit by neutrons. For a good bomb, the critical mass must be assembled quickly -- in millionths of a second -- so that as many of the atoms as possible can get hit by neutrons from other atoms before the blast scatters them. In practice, this means using some sort of explosive to drive the critical mass together.

Another factor is the density of the material. Normally, you would think that a particular metal has a certain density, and that's that. But when pieces of metal are being brought together with explosives, they strike with such a force that the metal itself is compressed to as much as twice its original

density. This enhances the chances that a given neutron will hit another atom before escaping from the material, and thus enhances the performance of the bomb.

Another factor is the use of reflectors. If the neutrons escaping from the material can be bounced back into it, they will have another chance to hit an atom. Most materials will reflect neutrons. Steel does so well enough for the purposes of many bombs. But beryllium is the preferred material. For various reasons of quantum mechanics, beryllium is the most likely substance to reflect a neutron. Beryllium is poisonous and hard to shape, but it is the material generally used in bombs.

With these factors in mind, let's go over the design of an actual atom bomb. The most straightforward design is the "gun" type. This was the type used on Hiroshima, and is shown in highly simplified and schematic form in the

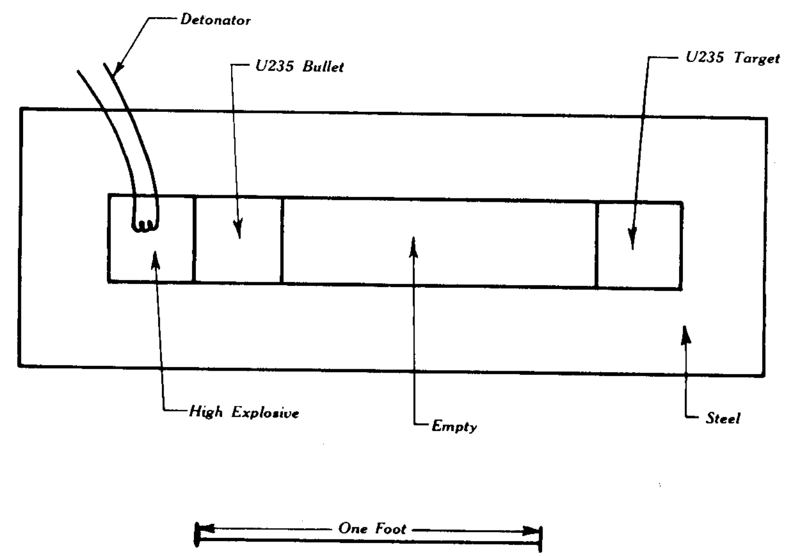

Figure 1:
U235 GUN (HIROSHIMA-TYPE) ATOM BOMB

accompanying illustration. A steel tube with about a three inch inner diameter is used. The walls are also about three inches thick. A surplus naval gun barrel will do for this. At one end, a slug of U235 is inserted, and the end is sealed. This slug is the "target". At the other end, another slug is inserted. This is the "bullet". These two slugs of U235 will combine to form the critical mass. Behind the bullet, a charge of high explosive is placed. Almost any explosive, from black powder on up, will do, but a plastic explosive such as RDX or C4 is preferred. An electrical igniter is embedded in the explosive, and the end of the tube is sealed. When an electrical current is passed through this detonator, the explosive will go off, sending the bullet down the tube at about 500 feet per second. The bullet hits the target, and both are compressed to twice their normal density. This process takes fairly long by nuclear standards -- perhaps a thousandth of a second. But U235 is fairly tolerant of this sort of thing. In the actual Hiroshima bomb, the bullet's back half was probably made of a neutron-reflecting material, and the target end of the barrel lined with the same material. In that way, the critical mass would be compressed within a shell of reflector. In such a crude bomb as was dropped on Hiroshima, sixty pounds of U235 were used. As we've seen, no more than about eleven pounds are needed in a well-designed bomb.

This is a good place to consider some of the reasons that making an atom bomb today is much simpler than it was in World War II. In the first place, they weren't sure which approaches might run into difficulty, and which not -- so two complete approaches were developed simultaneously (the gun, or Hiroshima type described above, and the implosion, or Nagasaki type described below). In addition, many other byways were explored, just in case they might come in handy. Today, the bomb maker can select the desired approach, and proceed directly.

Another major problem was doing the straightforward, but very tedious calculations involved. First, basic physical data

had to be crunched out, energy estimates, probabilities of neutrons hitting atoms, and so forth. Then the engineering calculations had to be done, hydrodynamic performances, optimum shapes and sizes, and so on. Huge rooms at the Manhattan Project were filled with hundreds of ladies working all day with mechanical calculators. Today, most of the results of those calculations have been published. In any event, the calculations could be re-done with a home computer in a very short time. The ladies did calculations with a speed of perhaps one calculation per second. Computers are normally measured in terms of millions of calculations per second. And they work around the clock, without careless errors.

Another troubling question was how much the mass of material needed to exceed the critical mass to give a good yield. Now we know: 110% to 120% of the critical mass. The figures mentioned above and below for amounts of fissionable materials include this consideration. We've already talked about the improvements in separation techniques. The huge amounts of power, and the enormous buildings, that the Manhattan Project required for separating U235 are no longer needed.

And finally, there were large numbers of theoretical types who spent their time wondering what was going to go wrong. What factors had been overlooked? Was there something unforeseen that would doom the project, or multiply its cost many times over? This same sort of phenomenon raised its head in the space program. Before the Russians launched their Sputnik satellite in October, 1957, the Vanguard project in the U.S. had stumbled forward. Once it was seen that the thing could be done, and in fact had been done, a U.S. satellite was up within four months -- using a launching system that had not even been thought of as a launching system until Sputnik.

Now let's consider the design of the Nagasaki atom bomb. This is a much more efficient design, and is the standard used today. The Nagasaki bomb was made with plutonium. A small

part of any piece of plutonium is the kind with a weight of 240. The rest weighs 239. Separating this heavier plutonium out would be even harder than separating U235 and U238. The trouble with the 240 weight plutonium is that it is very unstable. When you bring a critical mass of plutonium together, it is the 240 plutonium that starts to go into a chain reaction first. If you used plutonium in a Hiroshima type device like the one described above, it wouldn't work. In the thousandth of a second it would take the mass to assemble itself, the 240 plutonium would release its energy, scattering the 239 plutonium before it could be hit with neutrons. Plutonium has to be brought together in a period of millionths of a second. The method used for this is shown in the

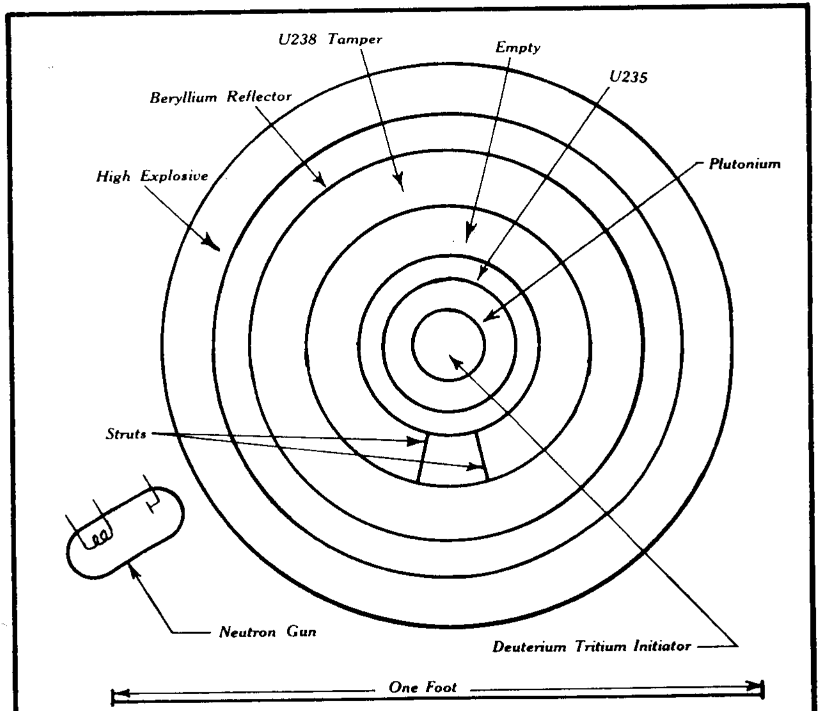

Figure 2:
PLUTONIUM IMPLOSION (NAGASAKI-TYPE) ATOM BOMB

accompanying illustration. It is so efficient that explosions with a force of hundreds of thousands of tons of TNT can be produced with less than fifty pounds of plutonium.

The outermost layer of the bomb is high explosive. This will exert about one-third of its explosive force inwards, compressing the rest of the materials. This is why it is called an "implosion" bomb. The explosive used has to be a high-velocity type -- the black powder that might have worked in the Hiroshima type bomb won't do here. Such explosives are known by names like RDX, or C4, or triamino trinitro benzene. Rather than be a continuous shell of explosive, there are twenty individual segments. The outer surface of the bomb is marked off in a pattern like that of a soccer ball, with twelve pentagons and eight hexagons. On top of each segment is placed a hemispherical charge of explosive, with the flat side towards the center of the bomb. An electrical detonator (not shown) is attached to the top of each charge, so they can all be detonated at precisely the same instant. The detonations must be simultaneous within millionths of a second -- within less than a millionth of a second if the bomb is to be used to set off a hydrogen bomb (see below).

When the explosive charges are detonated, they force the outer shell of the bomb inward. This shell is to serve as the neutron reflector when the atomic explosion gets underway, and the favored material for this is beryllium, though many other materials, including steel, will do.

Inside the beryllium shell is a shell of U238. This serves two functions. First, as a tamper. The rest of the bomb does not fill the space inside the U238 shell. Instead, it is suspended on struts, with an air gap around it. This air gap allows the U238 to build up speed as it is pushed inward, slamming into the rest of the bomb with enormous force. The principle of the air gap is the same as the principle of a hammer driving a nail. If you put the hammer's head on the nail and push, nothing much will happen. But when you move the hammer's head away

from the nail a distance and then push on it, the head builds up speed before hitting the nail. The momentum of the hammer's head is converted into enough force to drive the nail in.

The other function of the U238 is to serve as fuel for the atomic explosion itself. When the fissionable material inside the U238 shell explodes, it will release a flood of neutrons. In terms of released energy, this will do in a small fraction of a second what the process of converting U238 to plutonium in a reactor does over a long period of time. The U238 will be instantly converted to a fissionable form, and then fissioned. In a pinch, some material other than U238 could be used here, gaining the tamping effect, but not the boost of the extra fission.

The first thing that the U238 slams into is a shell of U235. This shell didn't exist in the Nagasaki atom bomb, which was entirely plutonium in its fissionable content, and it could be dispensed with here. Its effect is to boost the yield of the bomb. The plutonium at the core of the bomb fissions first. The U235 around it fissions more slowly. The U238 tamper fissions more slowly still, having to be converted to fissionable form to begin with.

Inside the U235 is the plutonium. As the hollow sphere of plutonium is shoved inward with great force, the critical mass is achieved, and the atomic explosion begins.

However, the space inside the plutonium shell isn't wasted. In sophisticated bomb designs, it is filled with material that is essentially a miniature hydrogen bomb. Because the space available is so small, however, this mini-H-bomb isn't able to contribute much to the yield, or explosive force, of the bomb -- at least, not directly. We'll talk about the makeup of the material in the H-bomb, and about what happens when it is exposed to the heat and pressure of an atomic explosion, in the section on hydrogen bombs below. For now, suffice it to say

that a large number of neutrons will be shot out of it. The idea of these neutrons is to help the rest of the fissionable material in the bomb to fission. Remember, the trick in an atom bomb is to get as many atoms as possible to fission before the energy released by the first atoms to fission blows the material in the bomb apart. Thus, when the bomb starts to explode, you want to have as many neutrons as possible generated as soon as possible.

To further increase the supply of neutrons at the start of the explosion, a neutron gun is mounted outside the bomb. This is a vacuum tube, in which tritium-containing material (such as is used in luminous watch dials) is heated on a wire filament. The tritium is then electrically charged, and shot down towards the center of the bomb by an electric field of about 3,000 volts. At the end of the tube nearest the bomb, it collides with a plate containing deuterium. The collision of the deuterium and the tritium smashes them apart, producing a stream of neutrons. Since the neutrons are not affected by the electric field (lacking any electric charge), they continue right on in the same direction, flooding the center of the bomb with neutrons. Remember, the neutron gun is only used at the moment that the chain reaction begins, after all of the material of the bomb has collapsed to the center. As an alternative source of neutrons, the radioactive element polonium can be used. This is an element widely used in laboratories around the world. A quantity of one-tenth of a curie is adequate. The polonium is placed on the surface of the fissionable material (just inside the air gap), and a disk of lithium (of atomic weight 6) is placed on the inside of the tamper so that it will be driven into the polonium. A shower of neutrons will be produced.

Hydrogen Bombs

We are now ready to complete our set of nuclear weapons with the big one. The basic process is simple to describe -- at high temperatures and pressures, deuterium atoms are forced together into helium atoms. Each deuterium atom has a proton

and a neutron. A helium atom has two protons and two neutrons. However, the helium atom has significantly less energy than the two deuterium atoms. This energy is released as the two deuterium atoms are combined (or "fused" -- hence the name "fusion" to describe the H-bomb process), and constitutes the energy of the H-bomb.

For reasons of physical laws, however, it is easier to get an atom of deuterium to fuse with an atom of tritium than with another deuterium atom. In numerical terms, it is about 25 times easier. That means deuterium atoms must be compressed to 25 times the density of deuterium and tritium, or must be held in compression 25 times as long. Or, since the tendency to fuse varies as the cube of the temperature, the deuterium atoms must be heated a little less than three times as hot as the deuterium and tritium. However, it should be kept in mind that this temperature relationship is true only within a certain range of temperatures. For each of the ways of fusing, there is a minimum temperature that has to be obtained. For deuterium and deuterium, a temperature of about 200 million degrees Celsius (360 million degrees Fahrenheit) is needed. For deuterium and tritium, a little more than a third of that is needed -- about 70 million degrees Celsius (126 million degrees Fahrenheit) will do. Therefore, it is customary to use a small quantity of tritium mixed with deuterium as a "starter", to get the deuterium hot and compressed enough for long enough to fuse with itself. Such a deuterium/tritium mixture is used in the core of the implosion atom bomb described above. Since tritium may be somewhat hard to get, it might be desirable to somehow get the deuterium to fuse with itself directly. We'll talk more about that later.

Ideally, one would just pack solid deuterium into the bomb. However, remember that deuterium is chemically about the same as hydrogen, which is a very thin gas at normal temperatures and pressures. It has to be cooled down close to absolute zero to get it to turn into a liquid. In early bombs, this

is what was done. However, containers for things that cold tend to be fragile, and the stuff tends to evaporate away over a period of time. Enclosing it in a container that would hold the pressure would interfere with heating it up when it was time to explode. Therefore, the deuterium is combined, atom for atom, with lithium to form lithium deuteride. This is a solid at ordinary temperatures and pressures. It is a white powder, which can be compressed into blocks with the consistency of aspirin tablets. One problem, though -- the stuff absorbs moisture from the air, and dissolves into a soggy mess. Even the moisture in your breath or sweat would be too much. Therefore, it has to be handled by people in completely enclosed suits with transparent helmets and piped-in air. If the lithium used in forming the lithium deuteride (and, of course, lithium tritide for the tritium) is the kind with the atomic weight of 6, the lithium itself is converted into tritium by the neutrons released in the explosion, and then participates in further energy release. But this energy is gravy, and ordinary lithium will do in a pinch.

The problem now is to get the deuterium and tritium to the temperature and pressure needed. In current bombs, these temperatures and pressures are achieved by the use of atom bombs. There are other ways to achieve the conditions for fusion, ways that avoid the need for hard-to-get fissionable materials. We'll talk more about them later. In many ways, the process of setting off an H-bomb is similar to that of setting off an atom bomb. In atom bombs, high explosive is used to stress fissionable materials to the point of explosion. In H-bombs, atom bombs are used to stress fusible materials to the point of explosion. And, as in atom bombs, the trick in H-bombs is to get as much as possible of the explosive material to release its energy before the very force of the explosion scatters the material.

The most straightforward approach to the H-bomb, therefore, would be to build it along the lines of the implosion

atom bomb, putting twenty atom bombs in place of the high explosive charges, and putting deuterium and tritium in place of the fissionable material. Actually, it might be possible to do the job with as few as four atom bombs around the outer shell, and in a makeshift H-bomb project, this might be the way to go. However, conventional H-bombs are more sophisticated. A technique is used that enables one relatively small atom bomb (such as the one described above, which would have the power of about forty thousand tons of TNT) to set off an H-bomb of any size (the largest H-bomb yet exploded had the power of about 58 million tons of TNT). Since conventional weapon delivery systems (bomber planes, ballistic missiles, etc.) can only carry a limited weight, a choice has to be made between one big bomb and a number of small ones. The latter are usually preferable. But for terrorists smuggling an H-bomb into (or near) a target in pieces, and assembling it there, the weight of a single device is less of an issue. However, the need for multiple triggers (one for each bomb) that use hard-to-get materials (fissionables and tritium) is more of a problem for the smaller group than for the major nation. Thus extremely big bombs enter the picture.

The technique used to get a single atom bomb to set off the H-bomb is the heart of the "H-bomb secret" as published by Howard Morland in the notorious article in *The Progressive* magazine of November, 1979. That technique is illustrated in the accompanying drawing. The bomb shown would have the explosive force of 300,000 tons of TNT -- a small H-bomb.

For the moment, ignore the "coffin" of U238 that surrounds the lithium deuteride and lithium tritide, and ignore the polystyrene foam. The key to the explosion is the outer shell of U238. This serves as a reflector, focusing the enormous radiation put out by the atom bomb onto the sides of the tapered cylinder of lithium deuteride. Some reflecting material other than U238 could be used, but U238 is favored because it will fission when subjected to the force of the fusion explosion,

and release still more energy. The shape shown here for the outer casing/reflector is only approximate. One of the major efforts in the original H-bomb program was calculating the best shape for this reflector. The ideal would be to have a shape such that any ray of radiation (most of the radiation is X-rays and gamma rays) starting at the center of the atom bomb at a given time would strike the outside of the tapered cylinder of lithium deuteride at just the same moment, no matter which direction it started out in. The radiation produced by the atom bomb moves away form the bomb just as if it had all started at the center of that bomb. It doesn't all leave at the same time, however. For the H-bomb to work right, though, the atom bomb must be set up to come as close as possible to releasing all of its energy at the same time. This is why tricks like the deuterium/tritium in the core of the atom bomb, and the neutron gun outside, are used -- to try to get as much energy released in as short a time as possible. In addition to all of the radiation ariving at the same time, you want the radiation to be spread more or less evenly over the whole tapered cylinder of fusion fuel. This is to avoid having the fuel squirt out somewhere where the pressure is a little less.

In the configuration illustrated here, an immediate problem would be that the radiation going directly from the atom bomb to the top of the tapered cylinder would arrive before any of the reflected radiation, and would tend to scatter the fusible material before the needed temperature and pressure could be achieved. Therefore, a block of U238 is placed in the direct path, to slow the effect of this direct radiation and cause it to effectively arrive at the same time as the reflected rays. In addition, the same tamping effect used in the implosion atom bomb is useful here. Therefore, the tapered cylinder is surrounded by a hollow cylinder of U238. To get the hammer-and-nail effect discussed above, a space is needed inside the U238 cylinder. However, because the lithium deuteride is fragile, it cannot just be stood up in the center on a couple of

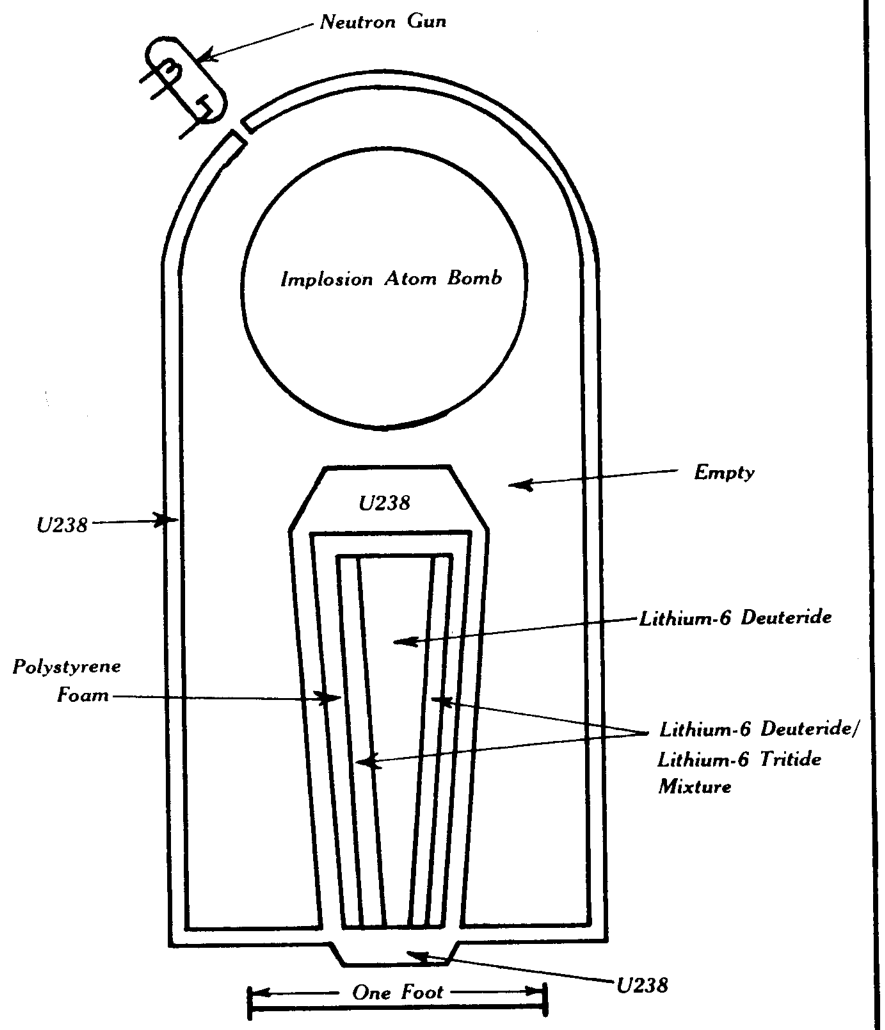

Figure 3:
HYDROGEN BOMB

struts, as was done for the fissionable material in the implosion atom bomb. Therefore, the space between the U238 and the fusible material is filled with polystyrene foam -- the same stuff used to make cheap picnic coolers, or to pack delicate equipment. This foam serves as packing material to protect the fusible material during the often rough process of delivering the weapon to the target. Under the temperatures and pressures of the explosion, of course, the foam is hardly more substantial than air or a vacuum, and does not interfere with the process. By the way, note that the outer surface of the tapered cylinder has lithium tritide combined with the lithium deuteride, to get the explosion started at as low a temperature as possible, and raise the temperature of the rest of the deuterium. Finally, note the block of U238 at the bottom to keep the fusion fuel from squirting out that way.

The method of designing the shape of the reflector is tedious but straightforward. If the fusible material were in a spherical shape, like the atom bomb, the problem would be simple. The reflector would be in the shape of an ellipse, with the atom bomb at one focus (a point near an end of the ellipse), and the fusible material at the other focus. However, there are problems with this configuration that have led to the use of a cylinder of fusion fuel. To spread the radiation over the cylinder, that end of the ellipse needs to be elongated. The exact shape is chosen by trying a number of shapes on paper. For each shape, each possible path a ray could take from the atom bomb is traced, using the basic law of geometric optics (the angle of incidence equals the angle of refraction -- known well to any pool player). This is the tedious part. When the H-bomb was being designed, it was no longer necessary to have **the rooms full of ladies with mechanical calculators that the Manhatten Project used. However, the electronic computers** that had replaced them were still rather primitive, and it took a long time to work out the right shape. With modern computers, the process should be much simpler.

A little earlier, I mentioned the prospect of starting a fusion reaction without the use of fission. This has been achieved in laboratories using a variety of means. In the search for fusion power, doughnut-shaped containers of deuterium and tritium have been heated and compressed by magnetic fields to reach fusion temperatures. However, the application of these techniques to H-bombs is hard to see. A more promising technique is the shining of powerful, tightly focused lasers on small pellets of fusible material. This has also been accomplished in the laboratories working on building fusion power plants. Lasers have been increasing in power and decreasing in price at a rapid rate in the twenty years since the laser was invented. It is reasonable to suppose that in a few decades, if not sooner, lasers good enough for starting fusion will be readily available or makeable.

An H-bomb without fissionables might be built by replacing the implosion atom bomb with a small spherical H-bomb. The same type of high explosives, beryllium neutron reflector, tamper, and air gap could be used. The fissionable core of the bomb would be replaced by a pellet of lithium deuteride/tritium mixture surrounded by a shell of fusible materials. The neutron gun would be replaced (or supplemented) by the laser, with a hole drilled to the center to let the beam hit the pellet. There are also indications that beams of electrons might be used to accomplish the same effect as the laser.

I also mentioned the prospect of a tritium-free H-bomb. In practice, this means achieving about three times the temperature needed for the deuterium/tritium fusion process. When using atom bombs, the temperature achievable is limited by the nature of the fission process. With lasers or electron beams, however, there isn't this fundamental limit. It is just a question of developing more powerful lasers or electron beams. How fast the technology of these devices will advance is hard to say. It might be useful, however, to look at the advance of the technology of the magnetic compression fusion machines.

Remember, the ability of a system to get fusion started is proportional to the density to which it can compress the fusion fuel, the time for which it can hold the material in compression, and the cube of the temperature (assuming the minimum temperature is achieved). Multiplying the density by the time and the cube of the temperature provides a "rating" for a system. Over the past decade, the rating of the best magnetic compression devices available has increased by about a factor of ten every two years. That is, the devices available in 1972 have a rating ten times that of those available in 1970, and the devices of the early 1980's, now under construction, will have ratings about a million times higher than those of 1970.

The difference between being able to start a deuterium/tritium fusion reaction and being able to start a deuterium/deuterium fusion reaction corresponds to increasing the rating about 25 times. This corresponds to about three years with the magnetic devices. The technology of lasers and electron beams might increase more slowly, but it seems reasonable to say that no more than a few decades would be needed. Therefore, in the long-term future that we're going to look at, we can expect to see bombs built without radioactive materials. By the way, such bombs present one solution to the energy shortage -- explode bombs underground, and tap the heat trapped in the rock. Some radioactive materials would be produced in the blast, but these would be short-lived. The main pollution problem with existing H-bombs is the uranium and/or plutonium involved.

Such low-pollution bombs also make the Orion spaceship propulsion system look more attractive. In this system, a spaceship is spring-mounted to a large plate, and nuclear bombs are exploded on the other side of the plate. The force of the blast pushes the ship up and along. This concept sounds like something right out of Rube Goldberg at first, but it is actually well-accepted in NASA and US Air Force circles, and

a considerable amount of theoretical and experimental work has been done, using chemical explosives. However, the Nuclear Test-Ban Treaty of 1962 forbids exploding nuclear devices in the atmosphere or in space, effectively outlawing the Orion ships. Nevertheless, it may be picked up by nations that have not signed that treaty, several of which already have nuclear weapons and others who seem likely to get them. This could be a shortcut for those nations to get space travel which, with nuclear weapons, are the major status symbols of the superpowers. If a nation is motivated to get nuclear weapons, the same motivation for prestige would push them to go into space.

In addition to getting H-bombs, however, they must be delivered to their targets to be of use. The obvious method is to smuggle them to the target, in pieces or assembled, as discussed above. Because H-bombs can be built as big as you like, it won't always be necessary to get into the target itself -- a big bomb can be set off nearby. In fact, a big bomb in orbit around the Earth can be set off in orbit -- about a hundred miles up -- and do vast damage on the ground. Or small rockets whose flight lasts only a few seconds -- too short to be intercepted -- can deliver a bomb the last few miles.

Errata

The above section on hydrogen bombs was written for the first edition of this book. Since then, more accurate information has become available.

The deuterium and tritium in the core of the atom bomb trigger is in the form of a highly compressed gas, rather than as the lithium compound. This could be prepared by pouring very cold liquid deuterium and tritium into a special capsule, and sealing it. As it warmed to room temperature, the gas would have no room to expand, and so would retain the high density of the liquid.

There is no lithium tritide in the bomb. The main charge is entirely lithium deuteride, with a barely-subcritical "pencil" of fissionable material (U235 or plutonium). Under pressure from the atom bomb, it is compressed beyond criticality, and explodes. The deuterium in the main charge is thus caught between two atomic explosions, producing the required temperature and pressure for fusion.

Finally, rather than the radiation pressure of the atom bomb pressuring the main charge directly, it is the polystyrene foam, vaporized by that radiation, that in turn puts pressure on the main charge.

Chemical and Biological Weapons

The dispersal of poisons and disease-causing organisms represents an extraordinarily easy way for those of limited financial and technical means to wreak mass destruction. In this section, we will consider three types of such weapons. The first is chemical poisons, the last is disease-causing organisms, and the middle one falls between the two.

Among the chemical poisons, by far the most suitable for a mass destruction weapon are the organophosphorous anticholinesterases (OPA's). These are so called because they are organic substances (that is, substances in whose molecules two or more carbon atoms are joined together) whose molecules contain phosphorous atoms, which act by inhibiting the enzyme cholinesterase. The cholines are chemicals made by the body to facilitate the transmission of nerve impulses. When they've done their work, they must be broken down to return the nerves to the resting state. Molecules of cholinesterase do this by attaching themselves to choline molecules, breaking them down, then going on to another molecule of choline. The OPA's look (to cholinesterase molecules) like choline molecules — except that once the enzyme has attached itself, they don't break down, thus effectively removing the enzyme from circulation.

This mechanism of operation has led to the OPA's being popularly known as "nerve gases" (though they aren't really gases, being inhaled or absorbed through the skin as a liquid). A German scientist first patented them in 1937, whereupon they were quickly incorporated into the Nazi war effort. The two forms favored by the military were Tabun (now known as GA) and Sarin (now one of the world's standard chemical munitions, known as GB). They are methylflourophosphoryl compounds. The V-series of nerve agents (including the widely-stockpiled VX) were developed subsequently. They are the methylethoxy thiocholine esters, and are the most toxic synthetic chemicals known, ranking with the quarternary choline and selenocholine OPA's.

Very tiny amounts of cholines are used by the body, and thus a very small dose of an OPA is enough to knock out the nervous system. The lethal dose in humans is typically on the order of one milligram (the actual lethal dose of a given substance can vary widely, depending on the individual involved and the conditions of administration; here, only order-of-magnitude ranges will be given: one milligram, ten milligrams, one-tenth milligram, etc.). This is a droplet about 1.33 millimeters in diameter (about one-third again the thickness of an American dime coin — not the diameter of a dime: the thickness). For comparison, the poisons beloved of the writers of mystery fiction (e.g., cyanide, or strychnine) have typical lethal doses on the order of 100 milligrams (corresponding to spherical pills with a diameter of about a quarter of an inch, or six millimeters).

A detailed cookbook for the synthesis of OPA's is provided in the U.S. Government publication *Superviolence: The Civil Threat of Mass Destruction Weapons,* further identified in the bibliography. It also covers the toxins and biological agents discussed below, and provides extensive references to the practical information needed to prepare and disseminate them.

As for why the U.S. Government is providing such cookbooks, the purpose is to demonstrate how easy the process is, and how widely available the necessary information and raw materials already are. The OPA's are also a major ingredient in the insecticides Parathion and Vapotone (also known as Tetron).

However, potent as these poisons are, they are still not potent enough to be true weapons of mass destruction. The problem is that of getting the substances into the systems of the intended victims. Getting victims to inhale enough of OPA's, or getting enough OPA's on their skin, is only practical in small areas (the 19th Century discoverer of the first OPA actually tasted his product without reported ill effect). For example, **when the entire U.S. Senate and House of Representatives, the President, all Cabinet members and all Supreme Court justices** assemble annually in the chamber of the House to hear the State of the Union Message, an OPA device might be used to decapitate the U.S. Government (actually, against just that possibility, one Cabinet member does not attend; in 1984, for example, that was the Secretary of Housing and Urban Development).

In current military doctrine, the OPA's would be used to force the enemy to go around in clumsy protective gear within a limited target area. No great number of casualties is expected, since that gear provides essentially complete protection (though of course there are always a few unfortunate soldiers). Any unprotected civilians around would, naturally, be annihilated; but then, military planners seldom worry about that sort of thing: that's what public relations officers are for.

In the popular prints, a common alternative to inhalation or skin contact is putting a poison in the drinking water supply. However, water (especially chlorinated drinking water) is a rather hostile environment for most complex chemicals or disease-causing organisms, and they tend to break down

quickly. No chemical or biological agent has the required combination of low lethal dose and hardiness in the water supply to make a practical water-borne mass-destruction weapon.

Another route of administration might be through the food supply. But rarely do enough people eat food from a single supply for this to be practical on a mass scale. Therefore, while the OPA's make good insecticides, they leave much to be desired as humanicides.

The next type of materials are the toxins. These substances are generated by living organisms, but the organisms themselves are not dispersed. Thus they fall between the chemical and the biological weapons. An example of these that has received recent notoriety is the trichothecene toxin, the active ingredient in the "yellow rain" reportedly used by the U.S.S.R. against the rebels in Afghanistan, and elsewhere in Southeast Asia. This toxin is produced by a form of grain mold. However, this and most other toxins have about the same lethal dose as the OPA's, so they are of limited interest as mass-destruction weapons.

In a class by itself is the toxin produced by the microorganism Clostridium botulinum. The toxin is known as BTX, and its effects are called botulism. BTX is roughly a thousand times more potent than any other known poison. A typical lethal dose is one microgram. This corresponds to a spherical pill so small that seven of them laid side-by-side would not equal the thickness of a dime. It is most effective when inhaled, which is also the most convenient way to deliver it as a weapon. About ten pounds of the purified toxin (or fifteen pounds of the 66% pure preparation described below) would provide a lethal dose for every human being on Earth. Five hundred tons (or 750 tons of the 66% pure product) would allow for a lethal dose to be delivered to each square meter (about 11 square feet) of the Earth's surface (land and

water), although the limited stability of the toxin in the air would become a factor in such large-scale use.

BTX works in the opposite way from the OPA's. Whereas the OPA's prevent the enzymatic breakdown of cholines (in effect causing nerve synapses (connections) to be stuck in their "on" position), BTX prevents the formation of the cholines in the first place (effectively freezing the synapses in the "off" position). Symptoms of botulism typically appear 12 to 36 hours after administration of BTX, though it can be as short as four hours or as long as four days. Early symptons are weakness, lassitude, headache, nausea and vertigo. Later symptons are double or blurred vision, pupil dilation, and rapid oscillation of the eyeballs. Then thickness of speech and difficulty swallowing set in, and possibly vomiting, constipation or diarrhea. The cause of death is usually paralysis of the breathing muscles after three to six days. No treatments are effective unless started before the symptoms appear (e.g., if a laboratory worker is known to have been exposed, treatment can be started immediately).

Botulism usually occurs as a result of the bacillus growing in a vacuum-packed can of food. The bacillus will not grow in the presence of oxygen, and so must be cultured anaerobically. A starter culture can be obtained from the soil, where the bacillus is essentially universally present. There are several different strains, however, and the most potent (type A) must be identified.

The first step is to innoculate enriched, glucose-containing culture media with the soil samples. The tubes of medium are incubated at a temperature between 10 and 37 degrees Centigrade (50 and 98.6 degrees Fahrenheit), in an atmosphere devoid of oxygen (typically, pure nitrogen). Those cultures that show a gram-positive reaction are examined microscopically for the characteristic appearance of the bacillus. Those that look right are put on egg-yolk agar plates

as streak cultures, and incubated in an oxygen-free atmosphere for two days. All strains of C. botulinus produce lipase, causing a dense, opaque zone to appear in the agar under the irridescent sheen of the culture colonies. These cultures are transferred to a meat-dextrose medium, and incubated at 24 to 30 degrees Centigrade (75.2 to 86 degrees Fahrenheit) for two to five more days.

At this point, the standard way to determine the strain of C. botulinum in a given culture is through use of the corresponding anti-toxin for that strain. However, if none of the anti-toxin is available, the various substances produced by the bacilli can be identified through standard microbiological techniques. These are made somewhat more tedious by the need to maintain anaerobic conditions, but the procedures are straightforward and well documented in the open scientific literature. All types of C. botulinum digest milk, gelatin, meat and coagulated egg or serum; they all reduce nitrate with the production of indole; and all produce acid from glucose, maltose, sucrose, lactose and mannitol.

Type A bacilli are distinguished from the less toxic types by fermenting cultures in a peptone and yeast extract mixture containing pyruvate and lactate. Only type A will produce isobutyric acid, isovaleric acid and isocaporic acid, while failing to produce lactic acid.

While these steps are basically straightforward, a modicum of technical expertise is needed to carry them out successfully. A trained microbiologist, or a high-school-graduate laboratory technician with a few years of applicable experience, should be able to accomplish them.

Once a starter culture has been established, production can be started. A corn-steep liquor medium enriched with casein and glucose, at a pH of 7.5, is used. The production could be carried out in a remote location; if discovered, it would merely appear that illicit alcohol (moonshine) is being made. Five

gallon carboys, filled with three gallons of liquor each, are convenient, if available. These are held at 34 degrees Centigrade (93.2 degrees Fahrenheit) for 80 hours. Then the liquid is brought to a pH of 3.5, causing a precipitate to form having about one fortieth of the volume of the liquid. This is washed and redissolved by adding calcium chloride and reducing the acidity of the solution to pH 6.5. The solution is filtered, and the solid material is discarded. The remaining liquid is brought to pH 3.7 to precipitate the toxin. Three gallons of original liquor yield 10 cubic centimeters (a little less than a cubic inch) of product (about 175 milligrams). This contains about half the BTX that was produced in the liquor, and is about 66% pure. If higher purity is essential, three more steps can be followed. However, about two-thirds of the toxin is lost in this process.

The cost of setup to obtain the initial seed culture is well under $10,000. For production, one or two three-gallon batches could be processed per week with the same basic setup. For higher production, continuous culture techniques might be used, or multiple parallel batches could be processed.

In dispersing the toxin, the main problem is avoiding excessive heat. At 65 degrees Centigrade (149 degrees Fahrenheit; typical of hot tapwater), the toxin is rendered inactive in an hour and a half. Another problem is non-acidic water. If water is neutral or alkaline, the toxin is destroyed in no more than four minutes. Drinking-water supplies are typically alkaline, due to the chlorine used for purification.

The best way to disperse the toxin is an aerosol. Night is the best time, to avoid any loss of potency due to photo-oxidation. Standard procedure calls for dispersal well above the ground along a line upwind of the target area. For greater persistence in the air, the toxin could be absorbed onto dust particles, which would be repeatedly stirred up into the air even after initial settling.

Finally, we come to the true biological warfare agents: disease-causing organisms that are released to infect the victims. A number of species are commonly considered for this purpose. Brucellosis, tularemia and desert fever are extremely potent, requiring less than one-twentieth of a microgram to infect a victim. However, no more than 10% of those infected die of these diseases, even without treatment of any kind. Therefore, they do not really qualify as mass-destruction weapons. Torulosis is an interesting case, in that it is more virulent against human males than females. However, the infectious bud cells are moderately delicate, making it difficult to disperse. Rocky Mountain spotted fever is difficult to culture, and is rather delicate when dispersed as an aerosol. Pneumonic plague is also moderately delicate when dispersed as an aerosol, and there is a vaccine available.

Thus the biological weapons of choice are narrowed to anthrax and parrot fever (psittacosis). In both cases, only about one-tenth of a microgram is required to infect a victim. Sixteen spherical lethal-dose pills would have to be lined up to reach the thickness of a dime. About a pound would be enough to furnish a lethal dose to every human being alive. Distributing a lethal dose to each square meter of the Earth's surface would require fifty tons of material (a cube about thirteen feet on a side). In practice, more than this would be required to annihilate humanity, but these quantities are within the range of an individual or small group to handle. Unmanned high-altitude ballons released in each of the Earth's six climatic zones (the two tropics, the two temperate zones, and the two polar regions) could effectively accomplish the dispersion.

The chief attraction of anthrax is that the active agent is a hardy spore that remains active for decades in the soil. It is estimated that a British island used to test anthrax dispersion techniques in World War II may be safe to inhabit without protective equipment in another century. Further, in addition to

being essentially 100% fatal if not treated, treatment can only save a small fraction of those infected. However, anthrax is not spread by human/human contact, requiring the intermediation of sheep or cattle. This makes anthrax useful for interdicting specific territory. With appropriate warning, casualties can be minimized.

On the other hand, if the most virulent strain is used, parrot fever is about 90% fatal untreated, while only about 10% fatal with treatment. However, it is contagious between humans, and thus makes an attractive doomsday weapon. A small initial infection in (say) a busy international airport or transit system could quickly become a global pandemic, swamping any possible treatment facilities. The five- to fifteen-day incubation period would allow the disease to become well dispersed before symptoms were noted (by contrast, anthrax requires incubation of only one to five days). Unlike anthrax, there is no known vaccine (posing an additional hazard to the preparer).

Parrot fever is endemic in South American parrots, and occasionally crops up in the U.S. on turkey farms. A starter culture can be obtained from the droppings of infected birds. There is generally a minor epidemic of anthrax among U.S. cattle each year, and it is a major problem in the European cattle industry. Thus, obtaining a starter culture would not be difficult. Parrot fever can be cultured in the yolk sacs of embryonated eggs, and in other rapidly-growing tissue cultures. Anthrax is optimally cultured at 37 degrees Centigrade (98.6 degrees Fahrenheit), at a slightly alkaline pH of 7.2 to 7.4. It grows well on many laboratory media. It is induced to form its infectious spores by reducing the calcium-ion concentration in the medium, and oxygenating it. Both anthrax and parrot fever grow well under the appropriate laboratory conditions. Parrot fever is moderately stable when dispersed as an aerosol, although not as durable as the anthrax spores.

The American Type Culture Collection is a not-for-profit institution that maintains standard cultures of a wide variety of disease organisms. Naturally, the more dangerous ones are provided to requestors only on a restricted basis. Anthrax was on the restricted list in the early 1970's, but (interestingly) parrot fever was not.

As with BTX, the preferred method of dispersal is along a line upwind of the target, from an elevated point. However, even ground-level release has been demonstrated to produce detectable concentrations of the active agent as much as 100 miles downwind. With a wind blowing onto the shore, a boat offshore can readily infect 100 square miles or more on land in a single release. A typical scenario for release from a small aircraft might involve 70 gallons of liquid, released along a thirty-mile line at an altitude of 100 yards, into a 12 mile-per-hour wind. The effective coverage area would be about 2500 square miles. However, it should be noted that the effectiveness of infectious agents can be seriously degraded by urban smog.

In the short term, the use of chemical and biological weapons by individuals and small groups is probably more likely than the use of nuclear weapons, because of their much lower cost and technical requirements. Nevertheless, one must not overlook the unique cachet that nuclear weapons have due to their being the ultimate weapon of choice of the superpowers, and the only weapons of mass destruction that have an actual history of use in warfare.

The moral repugnance toward chemical and biological weapons embodied in the official propaganda of the superpowers is a result of those powers' lack of need for those weapons, as opposed to their vulnerability to them. Since they continue to rely on nuclear weapons, their line toward those weapons must necessarily be muted. This may be a further factor militating in favor of nuclear weapons, or the cachet of

evil surrounding the chemical and biological agents may actually make them more attractive to certain potential users (just as outlaw motorcycle gangs adopt the symbols of Naziism and devil worship to express their rejection of conventional society).

In the longer-term scenarios discussed in the succeeding chapters, the impact of chemical and biological weapons may be much less. A nuclear weapon does its work by a brute-force technique: simply dumping a large quantity of energy in a given area (as the physicists put it, increasing the entropy in the area). There is little room for finesse in dealing with such an attack. Large masses of material are needed to absorb the energy if a target is to be hardened, or large buffer areas must be secured to keep such weapons at a considerable distance. These approaches are inherently costly.

On the other hand, chemical and biological weapons rely on finesse for their effect: interfering with delicate mechanisms in the body, such as nerve transmission. In principle, at least, this holds out the possibility of defeating them with corresponding finesse. For example, appropriate antidotes or vaccines or drugs might be developed to defeat the effects of the chemical and biological agents. Ultimately, an electronic device might be implanted in the body to monitor for the presence of such agents, and to take appropriate countermeasures immediately upon their detection — an artificial immune system.

Other Weapons of Mass Destruction

Nuclear weapons aren't the only manifestation of the increasing ability of human beings to change their environment. For example, as the exploitation of space advances, there will be activity in the asteroid belt. A slight push on a rock perhaps five miles in diameter would alter its course enough to intercept the Earth. A high-explosive charge would do to administer the push, something asteroid miners are

likely to have handy. By the time its deviation from its orbit had become noticeable from Earth, it would have built up enough momentum to make further changes in its orbit quite difficult to effect. If such a rock hit the Earth, it would have an explosive power of 300 times the biggest H-bomb ever exploded. It might very well send a ripple through the crust of the Earth (the outer few miles of solid rock that floats on the molten interior) that would effectively homogenize everything on the surface. This is before even considering the heat and radiation and atmospheric shock waves.

Or, material might be released in the upper atmosphere or in the space just around the Earth to break down the shielding effect of the Earth's magnetic field, or of the ozone layer in the upper atmosphere. Or the unlimited quantities of hard vacuum might be exploited to set up large particle accelerators very cheaply that could bombard the Earth with intense radiation.

All this illustrates why it is so urgent to get the human race into space as soon as possible. The Earth is a quite small and delicate place, human life on which could easily be wiped out by any number of (cosmically) trivial events. Sooner or later, someone with a grudge against humanity is going to do one of these things to commit suicide and take the whole planet with him.

The fact that space presents both the prospect for survival and the potential for destruction (through rock bombardment, etc.) presents a problem similar to that of bomb design: just as the bomb designer is in a race between releasing the energy of the nuclear explosive, and scattering the explosive as a result of that release, so the space planner is in a race between getting people established in space, and getting the Earth destroyed as a by-product of that activity.

Now that we have established the technical groundwork, we are ready to get back to the main topic of this book: the consequences of the existence of these cheap weapons of mass destruction.

CHAPTER FOUR
FROM HERE TO THERE

It is generally easier to anticipate long-term trends than to predict short-term events. In the next chapters, we'll look at where the proliferation of cheap weapons of mass destruction is likely to wind up. But most of us will spend most of the rest of our lives before things settle into any ultimate pattern, so it's worth taking some guesses at how things might get from here to there, and how we might survive the transition.

In the following discussion, it is assumed that the major powers avoid a general thermonuclear exchange. This assumption implies no assessment of the chances of such an exchange. It merely reflects the fact that whether such an exchange occurs depends on individual leaders, specific global situations, and other factors subject to chance. I have no particular expertise in analyzing those factors, and will not attempt to make guesses on this point. If such an exchange occurs, obviously the situation changes radically. It is not even sure that human life would survive such an exchange.

This brings us to another assumption. Whether or not a general thermonuclear exchange occurs, it's not clear whether human life on Earth would survive any transitional period of mass destruction weapon use to reach the long-term quasi-equilibrium discussed in the next chapters. Obviously, if it doesn't, there's nothing more to say. Therefore, just for the sake of keeping the argument going, it will be assumed that humanity survives. Again, this doesn't imply any assessment of the chances of annihilation.

Global Scenario

Possible early users of cheap weapons of mass destruction include people with a real (or imagined) grievance against major institutions or society (such as New York's notorious

Mad Bomber), extortionists (demanding their monetary payoffs or political concessions), political extremists (merely wishing to show their power or get revenge, without conditioning their act on the meeting of specific demands), or even alienated technicians fascinated by the possibility of home-brewing a weapon of mass destruction and using it "because it's there" (essentially, pyromania writ large; this effect was observable among the scientists who built the first atom bomb during World War II, though they weren't in a position to make the decision to use or not use it).

It is pretty well established that the current policy of established authorities toward mass-destruction extortion threats (there have been some hoaxes already) is not to publicize the threats (lest panic ensue), nor reward them (lest others be encouraged). This policy means that rational extortionists will tend to be discouraged, but it doesn't affect the other categories I've mentioned. Even regarding extortion, one must always expect there to be some people desperate enough to run the risks anyway. Eventually, someone will actually use a mass-destruction weapon on a population center. At this point, the situation starts to change drastically.

Airplane hijackings were technically possible with the introduction of intercontinental air service after World War II, but weren't seen until the 1960's. However, once they started, other potential hijackers quickly picked up the idea, and they became commonplace. Similarly, the technological means for individual or small-group weapons of mass destruction have been present for some time, but the right conjunction of personnel, motive, circumstances, etc., to precipitate an incident hasn't yet occurred. However, once one such incident occurs, it can be expected that a relatively large number of potential users of cheap weapons of mass destruction will pick up the idea.

Immediate consequences of mass-destruction incidents may include domestic crackdowns by governments, hoping to nip any plots in the bud. Panicked populations may well tolerate far harsher measures without open rebellion than they would now. However, this would at most thin out the threats. As with airplane hijackings, the security measures in place catch mainly the incompetents and amateurs, people who haven't thought through their plans. When serious people want to hijack an airplane, they don't have too much trouble smuggling aboard non-metallic weapons (knives of hard plastic, bombs, etc.). The technical skill required to make mass-destruction weapons, though by no means rare, will weed out the half-cocked attempts in any case. It is questionable how much more any sort of feasible security measures could hope to accomplish in a mass society (within smaller groups, where most individuals are known to each other, security against internal threats is more practical).

At the same time, governments may be tempted to threaten retaliation (conventional or mass-destruction) against foreign countries alleged (accurately or not) to be harboring or aiding mass-destruction terrorists. However, this will tend to provoke nation-to-nation confrontations. A given nation pursuing such a policy would risk finding itself in such confrontations any time any city within its territory was threatened. A smaller, independent unit could stand clear unless and until it itself was directly threatened (another factor favoring smaller units over larger ones).

Governments that meet the demands of extortionists mark themselves as easy targets for others. This is why most governments today have a no-ransom policy regarding political kidnapings. This is well and good for the government, which can survive the loss of a single individual or small group of victims. But the families and employers of the victims stand to suffer considerably more, and tend to be more inclined to

pay the demanded ransom. Thus large ransoms (in the tens of millions of dollars — more than enough to finance a mass-destruction weapon development project) have been paid by the families and employers of American business executives kidnapped in Latin America.

Similarly, national governments are likely to take a no-ransom (financial or political) policy against mass-destruction threats, while the localities directly threatened make their own deal (acting through municipal governments, or groupings of major business interests in the area, or other unofficial channels). Furthermore, the capitals of nations, or other cities closely associated with support of a national government will be a likely target of those aiming at the national government itself. Thus there will be a tendency for cities to try to dissociate themselves as much as possible from their nation's policies (particularly hard-line policies like no-ransom and massive-retaliation). This will provide a further centrifugal impetus.

As time goes on, no large city can expect to escape direct attack indefinitely. Such cities provide a very rich, concentrated target. Their diverse nature tends to create tensions between groups within them, giving motives for grudge attacks. The anonymity of their populations makes it difficult for them to impede the smuggling in of mass destruction weapons, or the assembly of such weapons within their borders. The precise critical sizes of cities are hard to estimate, but it seems likely that any city over 100,000 population will be caught in this bind, while any community of 100 should be in good shape. Between those sizes, things may depend on specific circumstances.

Nations were invented about 10,000 years ago, at the same time as agriculture and animal husbandry, to control the newly-created food surpluses. Cities were then instituted by the nations as nexuses of transportation and communication, to implement that control. As the cities are picked off one by one,

the grip of the national governments will weaken. Individual military units will look after their own future, throwing in with local authorities, or assuming such authority themselves. This will add to the supply of generally-available weapons of mass-destruction. The erstwhile national government (by that time, those that have survived will probably be ensconced in deep bunkers under remote mountain ranges) will devolve toward being just one more local authority, albeit perhaps more powerful than the average one. A good analogy might be the situation in Lebanon in the early 1980's. Gradually, the nominal government was reduced from controlling the entire country, to just a shaky grip on one neighborhood of the capital.

People in large, stable countries like the United States may tend to respond to the above by saying, "It can't happen here." To be sure, the tradition of being a single, cohesive nation is strong, and will not be universally overthrown overnight. Some people may react to the proliferation of mass-destruction weapons like Harry Truman. Not the American President, but his namesake resident of the slopes of the Mt. St. Helens volcano. Warned that an eruption was imminent, he refused to leave, saying he'd rather die than leave his beloved forest. He got his wish when the top blew shortly thereafter. Similarly, many if not most people may cling to their old habits until their city is hit. However, since we're assuming some people survive, eventually those who are cleverer, those who are more ambitious, those with sharper pencils, will start to realize where their interest lies, and make the break with tradition. It is these people who will shape the future, not those who cling to traditional ways.

Governments, like the dominant individuals in any mammalian social group, derive their respect from their demonstrated ability to enforce their control over members of their group, and their ability to hold external threats at bay. In the short-term, attack from without can be used as a rallying force (e.g., England during the blitz of London). But as enemies are seen to wreak mass destruction at will, with no prospect of shutting them off, governments will lose much face. As individual localities cut their own deals with extortionists, respect falls off even more, accelerating the process of disintegration.

The people with the best chance of survival will be those in smaller groupings, relatively isolated from major population centers. If the group is relatively homogeneous in terms of people's interests, the chances of internal dissention leading to an incident will be reduced. If the group is located away from the territory of a national government that has made many enemies (e.g., in a small, neutral country), that should also help. Such groups would be well advised to keep a low profile, both in terms of keeping their wealth inconspicuous (avoiding attracting financially-motivated extortionists and envious political and grudge bombers), and avoiding being associated with contentious political issues as much as possible (as New York City is associated with support for Israel, or Lynchburg, VA, is associated with right-wing preacher Jerry Falwell). Survivors living under circumstances that don't fit the above description will likely seek to form new communities that do meet those specifications, in areas removed from present habitation.

Personal Strategy

The key to survival through the above scenario is timing. One should not panic and make premature moves, nor should one ignore events until it is too late.

At this writing, there is no urgent need to act. The use of cheap weapons of mass destruction is likely to begin with an isolated incident, then others with increasing frequency, much like a batch of popcorn popping. Although one may wish to

relocate if one lives near a particularly attractive target (e.g., Washington, DC, or New York City), in general one can reasonably wait for the first incident before making one's move. To be sure, others will have the same idea, and the cost of suitable sites, supplies, etc., may be higher than earlier. But most people will wait longer than that to act, so things shouldn't be unreasonable. In exchange for waiting, one can enjoy the amenities of the big city longer, and can accumulate more capital (generally, incomes are higher in or near cities for given jobs or businesses). Furthermore, one would then have a wider choice of associates. At present, many of the people moving to the hills in anticipation of social collapse seem to be borderline paranoids in camouflage suits, or nervous nellies afraid of the sky falling. If these people have such a poor sense of timing as to panic now, one would not want to trust their judgment in subsequent crises. In addition, because of the small number of people taking to the hills now, each such effort attracts a lot of media attention, which could attract mass-destruction wielders and other undesireables later on. Waiting for the first incident, when a fairly large number of communities would be organizing, would afford greater anonymity.

Just this morning, as this is written, a fellow on television was bragging about how he realized the danger of Hitler in 1922. Perhaps he did, or perhaps he just made a lucky guess. My Jewish father was living in Germany at the time, and by 1933 had seen the street violence against Jews begin, and had been forced to leave graduate school because of his background. He left for the United States that year, still in plenty of time to avoid personal danger (the early street violence was much like urban muggings in one sense: one could easily minimize the risk by avoiding certain neighborhoods at certain times). Even then, it wasn't a matter of forseeing the concentration camps that were to come. He merely saw that, as a Jew, he could expect harassment, and

saw no reason to bother tolerating it. But others rationalized that they would muddle through somehow, and refused to seriously consider flight until it was too late.

Thus the key to it all is not having great foresight, but being willing to act on what is obvious at any given time. One must neither panic prematurely, nor hide one's head in the sand, Harry-Truman-like. As Shakespeare's Polonius advises his son Laertes in Hamlet, "Be not the first by whom the new is tried,/Nor yet the last to leave the old behind." Cynical perhaps, but good advice in dangerous times.

When moving to a place such as described above, don't forget to convert your assets out of vehicles denominated in government currencies. As the governments lose their grip, their money will lose its value. Precious metals remain a safe, conservative store of value. There's no need to speculate with comodities like pharmaceuticals or microelectronics or other things that might become scarce after a breakdown of nations, unless one is a speculator by nature. Such speculation requires far better timing to be successful than does mere survival.

As a final note, extensive "hardening" measures for facilities (putting them deep underground, surrounding them with concrete, installing elaborate air filters and shock resistant mountings, etc.) may be in order for high-value installations that can't readily be dispersed (e.g., integrated factories). However, in the case of residential areas, such measures seem likely to attract more attention, offsetting the advantages gained. Low-profile anonymity still seems to me the best approach.

CHAPTER FIVE
POLITICAL STRUCTURE

In considering where (in terms of political structure) the proliferation of cheap weapons of mass destruction might ultimately lead, it's useful to go back to the beginning of things — say, several billion years.

Life first emerged as protein molecules capable of assembling replicas of themselves from the surrounding medium, not unlike viruses or even simpler entities that survive to this day. Each type of molecule was on its own, competing against all other molecules for the available raw material, desireable locations, etc. In time, some of these molecules joined together to form organelles, some of which joined to form cells, some of which joined to form organisms. Much later, some of the more complex individual organisms (e.g., birds and mammals) got together to form families, and families combined into small social groups. These aggregated units then competed to produce as many copies of themselves as they could.

At each juncture, the critical question determining whether a combination would prosper and survive, or fail and die, was: what's in it for the combining units? Do the units gain by combining, or would they be better off each looking out for Number One? Aggregations of the above types have all been around for millions if not billions of years, and their advantages have been well established by long experience. In such combinations, economies of scale can be realized, division of labor can be practiced, and so on. There is no evidence to suggest that these facts have changed much in the past few million years, or that they are likely to change in the forseeable future.

To be sure, such combinations aren't necessary for survival. Viruses, single-celled life-forms, individual organisms that live

alone and those that live in isolated families continue to be found. Even among present-day humans, some people choose to live as hermits in remote areas. Still others choose to live as families on isolated homesteads and the like. In the future, no doubt these life-styles will continue to attract a certain number of adherents. Several books in the Loompanics catalog (see the Bibliography) give practical advice for such people.

However, they require considerable effort to establish and maintain, and, throughout history, most people have preferred to live in groups of at least several families, to gain the advantages discussed above. For most of the million or so, maybe more, years that humans have existed, the hunting/gathering band was the standard form of organization. This consisted of several dozen to perhaps a hundred or so individuals, the adult males and females paired off, and the young associated with their parents. Opportunities for larger groupings were limited: if a group got too large, it had to range too far afield to hunt and gather enough food. One group might occasionally raid a neighboring group, seizing what that group had, and killing the rival group (or just leaving it to starve). But attempting to dominate the members of a rival group on an on-going basis wasn't feasible: if the conquerers took enough food from the vanquished each day to feed themselves, the latter soon starved and the game was over.

All this changed about 10,000 years ago, when agriculture and animal husbandry were invented. A subject people could produce enough food to feed themselves with enough left over to feed a number of conquerers sufficient to keep them in thrall (typically 5% to 10% of the population). At this point, the maxim "God is on the side of the big batallions" gained sway, a sway it has held for 10,000 years. The overall trend of this period has been toward fewer and larger groupings (of course, this process has not been uniform: empires fall and break apart as well as grow; for a fuller discussion of this process, see my

"General Theory of History" in issue #108 of *The Connection*, described in the Bibliography).

In terms of our earlier discussion about the advantages of combination, we might imagine a small group facing an expanding empire, and asking it, "Why should we bend our knee to you? Why should we pay you the tribute you ask? Why shouldn't we tell you that we are, and of right ought to be, free and independent, and that you can go to Hell?" Putting the best face on things, the empire might respond, "We can protect you from other marauding empires bent on sacking you better than you can protect yourself alone. We can establish a fortified frontier around all the groups in the empire, and thus have to defend only the outer ring of groups. With the inner groups contributing their taxes, each of the outer groups can be defended much more strongly than they could hope to do so themselves." In a more cynical vein, the empire's response might be, "You should bend your knee to us, and pay the tribute we demand, because if you don't THIS marauding empire will sack you." Expressed either way, the argument is cogent: the isolated band cannot stand alone, and must be incorporated into one empire or another.

But with the application of the scientific revolution to warfare (beginning with guns and intercontinental sailing ships, and leading to cheap weapons of mass destruction), the situation changes. No longer is God so clearly on the side of the big batallions; no longer can a large empire crush a small foe at minimal cost and risk. With cheap weapons of mass destruction, even small belligerents can inflict grievous harm on even large opponents. The situation is analagous to a tiger facing a venemous snake. Although the tiger is much larger, and could easily kill the snake, the snake would likely get one good bite in first, killing the cat or making it very sick. No tiger can prosper in a life-style that requires the systematic bullying of snakes. One is reminded of the American Revolutionary

War flag with the coiled rattlesnake and the slogan, "Don't Tread On Me."

Furthermore, the importance of geographic contiguity is substantially reduced. The fortified frontier, manned by a standing army, is of limited value against a weapon of mass destruction that is smuggled into its target area, or clandestinely manufactured on the spot, or delivered by intercontinental aircraft or missile.

Returning again to the question of the advantages of combination, a small group can say to a threatening empire, "Any aggressive moves against us will cost you dearly; don't tread on us." If the empire talks about the advantages of its security cordon against other empires, the small group will say, "What good are your strong-held walls? We're worried about mass-destruction attacks, clandestinely or intercontinentally mounted. What can you do for us against them?" The empire can promise to threaten mass-destruction retaliation against any such attacker. But because geography isn't much of a factor in such retaliation, a given small group need not deal with any specific retaliator to gain this sort of protection. Such a group can shop around the world for whatever retaliator offers the best terms for its protection (assuming that the group does not want to undertake its own retaliation). Thus, providing protection becomes a highly competitive, scratch-and-survive business. No longer can an empire dominant in one geographic area extract what the economists call "monopoly rents" from the people and groups in that area because potential competitors cannot penetrate that empire's borders. No longer do rich streams of tribute flow to the imperial capital. Instead, those who follow the profession of arms can only hope, with the aid of sharp pencils and effective marketing, to get enough revenue from those under their protection to pay the costs of maintaining their retaliatory forces, and provide enough profit to make it worth their while,

but not so much profit that excessive competitors are attracted into the field.

Thus freed of dependence on a given protector, the individual small groups would be essentially independent. That leaves the question of how the small groups might be organized internally.

One vision is of communal democracy, in which the residents all have an equal voice, and decide matters by reaching a consensus. This approach has been tried from time to time, and will no doubt continue to attract enthusiasts in the future. But, like living as a hermit or on an individual family homestead, it makes heavy demands on the time and energy of the participants, and (as at present) most people will probably prefer an approach that leaves them more free to pursue other interests.

Another conceivable approach is that favored by some followers of novelist Ayn Rand, and others calling themselves "anarcho-capitalists." In this approach, each person is an independent economic agent, and negotiates with all other persons in the group on a contractual basis regarding any matters that involve more than one person. Again, this is very demanding in terms of time and energy, and while a few enthusiasts will no doubt want to try this, most people will not be so motivated.

Instead, most people will likely follow the present practice, in which a single individual (king, president, chairman, etc.) or small group (legislature, council, junta, etc.) has control (possibly subject to some ultimate accounting, such as elections, but not effectively questionable on a day-to-day basis) over certain key areas of life in the group (the police/military area is fairly critical, but centralization of controls over matters such as roads, religion, sanitation, etc., may vary).

This leaves the question of how the organ of this central control might be structured. Again, there are a number of possibilities, and in this regard I would expect to see more diversity than in the case of the choice of a small, centrally controlled group itself. However, there is one form of organization not normally considered by political science that I believe would have significant appeal in the coming world of cheap weapons of mass destruction. This is the proprietary community, which is more economic than political in the traditional sense. Therefore, its discussion is left for the next chapter.

CHAPTER SIX
ECONOMIC STRUCTURE

In the previous chapter, we established the trend toward the decline of the nation-state, and the decentralization of political power. This leaves the question of how economic relations between individuals spread among these dispersed entities might be conducted. That is the subject of this chapter.

The multi-national corporation has been put forward as a possible successor to the territorial nation-state as the predominant force in the world. Those advancing this view point to the techniques that such corporations use to shift assets, profits and operations from jurisdiction to jusrisdiction, in order to defeat attempts by individual nations to impose their wills on the firms: profits are shifted to low-tax countries by sham transactions, plants are moved to low-wage areas, and so on. But these efforts at regulation by states and evasion by corporations are largely superficial. On a more fundamental level, these corporations are creatures of the nation-states, and completely dependent upon them for continued existence.

To illustrate this dependence, consider the case of a corporation with far-flung branches. Along the lines of the discussion in the previous chapter of the merits of combination, why should the manager of a branch plant take orders sent out from headquarters? Why shouldn't he just tell the corporate brass to take a flying leap? One possible reason is the desire to continue profitable trade. Headquarters orders the branch to ship certain parts for use by another part of the firm, and says it will not ship the branch's monthly payroll until the parts have been sent. If the manager finds this exchange advantageous, then he will ship the parts. However, at this point the branch is acting not as a part of the parent corporation, but as a separate firm, and independent supplier. There is no reason this sort of relationship shouldn't continue even in the absence of nation-

states. The various suppliers might even find it advantageous to put the same name on the outside of their buildings (IBM, or General Motors, or whatever), to let the people they do business with know that they cooperate with each other.

So how is this different from being branches of the same firm? The key area is matters in which ownership of the underlying assets, rather than ongoing profitable trade, is the issue. For example, suppose one branch has built up a sizeable cash surplus, and headquarters orders it remitted for distribution to the stockholders. The branch manager might be tempted to pocket that money himself. And why shouldn't he? If the home office, in a fit of pique, refused to send any more paychecks (i.e., refused to continue "buying" the plant's parts), the manager might conclude that there are plenty of competitors who would be glad to buy the parts. That is, he would analyze the situation as an independent entrepreneur rather than a corporate employee, and reach a different decision as a result.

Or perhaps headquarters is grooming an up and coming young man, and decides that he needs experience running a branch plant. An order goes out to the branch manager to clear out his desk by Friday afternoon to make room for the new man. The current manager might decide that, because of his age or other factors, he is unlikely to get as desireable a job as he now holds. Why shouldn't he turn away the home office's fair-haired boy at the gate?

In fact, why shouldn't the branch manager send similar orders to headquarters? Why should headquarters expect the branch to obey its orders any more than it obeys the branch's orders?

Insofar as the conditions of the agricultural era continue to prevail, the answer lies in the territorial nation-state. In such cases of insubordination, the headquarters people can go into a court and get a writ demanding that the branch manager obey.

The police or army of the state will then take that writ, and enforce it on the branch manager: confiscate the profits to be remitted, bodily remove the manager from the premises, or whatever is necessary to work headquarters' will. If a branch manager goes into court to try for such an action against headquarters, he will be rebuffed.

Thus the operation of the major corporation as we know it depends on all of the activities in question occuring within a common jurisdiction or (if spread over several jurisdictions) requires that all jurisdictions involved are agreed on the basic principles of ownership and control. These jurisdictions may not be very enthusiastic about these principles, but value the benefits of the corporations' presence enough to swallow their reservations and sign off on the appropriate commercial treaties. Within those treaties, nations may jockey for advantage in terms of wages, taxes, etc. But the necessary condition for corporate operation is that, when the chips are down, the state backs up the authority of corporate headquarters.

Because of the advantages of geographic contiguity in agricultural-era warfare discussed in the previous chapter, it is not feasible (under agricultural-era conditions) for a corporate headquarters to attempt to maintain independent military forces that it might dispatch to remote locations to enforce its will. The local nation-state at the remote point will tend to have a decisive advantage. In the world of cheap weapons of mass destruction, a corporate headquarters trying to impose its will on a remote group would be in the same situation as any other would-be empire builder: they would be unable to give a good answer to the group as to why that group should submit to them, or should deal with them on any basis other than mutual advantage on a case-by-case basis. To be sure, for a time traditional emotional ties and simple inertia might incline a "company man" running a branch plant to go along with

corporate HQ. But a few plant managers who were more aggressive and ambitious, who had sharper pencils, would sooner or later start to raise awkward questions about remitting profit, stepping aside for people from HQ, etc. And when others saw that they got their way with their insubordination, and profited by it, they would follow suit. Eventually, the organization would fall apart, except as a loose grouping of mutual suppliers and customers, each acting as an independent, profit-maximizing agent.

In the current world, there are some factors that tend to mask the corporation's status as a creature of the nation-state, and make it appear that the tail is wagging the dog. For example, it must be kept in mind that the institutional primacy of the state over the corporation doesn't directly determine which individuals will be dominant overall. In a given situation, an individual with a sign on his office reading "President of the Republic" may be in charge, and pick up his phone and give orders to someone with a sign "Chairman of the Board" on his office. In another situation, it may be the Chairman of the Board who effectively gives orders to the President of the Republic. There's an old Scottish saying: "Where MacGregor sits, there's the head of the table." The fact that the dominant individual finds it most convenient to style himself an officer of a corporation rather than of a state doesn't change the fact that it is control over the machinery of the state that is central to his power.

A scenario that has recurred in science fiction has been that of corporations actually abolishing states, and ruling directly. If such a thing happened, the organization would no longer be operating as a corporation, but as a new state. The officials of the new state might be the same as the officials of the old corporation, and they might retain the same titles and work in the same office buildings, but they would no longer be operating as a business firm. At that point, their success would

no longer rest on their ability to produce a good product at a good price and make a profit, but on the same basis as any other state: their ability to motivate people in their jurisdiction to fight enthusiastically for the state, at minimal wages, and to bear the cost of such warfare (through taxes, or however the new state might raise a war chest). If rival states were more successful at this, all of the corporation's business acumen and success would mean little. And history has shown that states that were incompetent economically have nonetheless won great victories in war, and have prospered. Thus little change would have occurred on an institutional level: only the names of the state, and of its offices, and of its incumbents, would have changed.

Thus we see that, in the future world of cheap weapons of mass destruction where traditional nation-states can't operate, business must be conducted by independent, entreprenurial units. This raises a problem of how capital might be raised for such activities. After all, at present, the ability of stockholders to rely on receiving their dividends on their investments rests on the same basis as that of corporate headquarters receiving the profits of their subsidiaries: if management simply walks off with the accumulated profits, stockholders can (theoretically) sue in court. And if management is inclined to play games by inflating their own salaries, giving themselves big expense accounts, etc., so that no "profits" ever materialize, there are various regulatory agencies that (theoretically) enforce rules in these areas. If profits are simply allowed to accumulate in a company, stockholders (theoretically) can realize those gains by selling out to a corporate 'raider' seeking to take over the company and liquidate it.

However, even at present, those recourses are at best limited, and corporate management has succeeded in getting laws and regulations on the books that aid their position vis-a-vis the stockholders: double taxation on dividends discourage

demands to pay them out, complicated bookkeeping rules that let inflated salaries and expense accounts be slipped through obscurely, and laws that put obstacles in the path of takeover attempts. While the state has an interest in seeing to it that public confidence in the whole investment process is maintained, that interest generally extends only to supressing some of the more egregious ripoffs that might spoil things for everybody (just as a gambling casino limits the percentage taken from the bettors, because if they lose too much too fast, they'll go away mad and not bring any more money in). However, in the absence of states (i.e., in the world of cheap weapons of mass destruction) even the appearance of such defense of investor interests will be gone, and those seeking capital will have to come up with some other way of inspiring investor confidence.

One step in this direction would be reliance on debt rather than equity financing. Under debt financing, the investor knows exactly how much he is due at what time, and can easily tell whether he is getting his due. If he advances a firm 100 ounces of gold at 6% per annum, either he receives his half-ounce of gold each month or he doesn't. There can't be any arguments over how "profit" is to be computed.

This still leaves the question of how one can be confident that the stated terms of the debt will be adhered to. Why shouldn't the debtor just abscond with the proceeds of the loan or bond issue? After all, there aren't any courts the investor might turn to, nor regulatory agencies. In this area, the key will be the reputation of the individuals, families and firms involved. The longer a given individual, or family, or firm has spent building up a reputation for reliability, the more they have to lose by absconding, and the more they have to gain by continuing their reliable behavior. For example, the banks in Switzerland could easily get the Swiss government to pass a law allowing them to seize their foreign depositors' money as

their own. But they don't do this, because nobody would ever deposit any money in a Swiss bank after that, and that future business is worth far more than the immediate profit of confiscation.

Of course, there would always be suckers willing to jump at the promise of high returns, and not look too closely at the quality of their investments. And so there would be confidence men eager to take them for all they were worth. This faces the small investor with a difficult problem: how can he sort through all the hype and find the prudent investments? In general, he won't be investing enough capital to make it worthwhile to conduct an extensive investigation before investing, nor supervise his investments closely.

The solution is what the economists call "intermediation": the small investor gives his money to an intermediary (e.g., a bank) in exchange for a promised rate of return (interest). Since he will be putting all, or a large part, of his capital in one bank, the small investor can afford to check out the bank's reputation. Also, because banks can invest in any business anywhere, there would tend to be a relatively small number of major banks, compared to the large number of firms in individual businesses; there would be no need for a small investor to inquire into the reputations of large numbers of marginal enterprises.

Each bank, in turn, would invest its depositor's money in firms. Because the bank is investing a large amount in each firm, it is worth its while to check the reputations of the individuals, families and firms involved, and to ride herd on subsequent performance to detect incipient problems.

While there is a good deal of intermediation in investment today, there remains a substantial segment of individual stock ownership. If the advantages of intermediation are as described above, why then do these people invest individually? The

answer is that, basically, they are suckers. One has only to look at the ads for the brokerage houses to see that people are induced to invest their money through the express or implied promise that they can make a killing, that the ABC Brokerage Company can give them "inside information," can find the "needle in the haystack," etc., that will let them outdo some other poor sucker. In fact, every study of the securities market has shown that no brokerage house's customers have consistently done better than average, and many have done worse. And it takes only a moment's reflection to realize that, if a broker really had the information needed to beat the market consistently, he'd hardly be giving it out free or at nominal cost to individual small investors walking in the door.

However, just as the success of gambling casinos depends on limiting the take in the games, so the maintenance of the brokerage business requires that the more egregious scams that would sour people on the market as a whole be suppressed, so that the "reputable" brokerages can steadily milk their customers for commissions. This suppression function is performed by the state through courts, regulatory agencies, etc. The state has an interest in doing this, because as long as people can think of themselves as budding Rockefellers or Morgans, with a chance to hit it big on Wall Street, they are less likely to be sympathetic to politicians who talk about making major changes in the way things are run.

But as the nation-states decline, they will no longer be able to provide this service, and the illusion of the little guy beating the market will be essentially impossible to maintain among all but the most gullible. Thus one can expect a major trend toward more intermediation of investment.

This leaves the question alluded to in the previous chapter: how the small units into which the world will be organized might be administered internally. In the agricultural era, the key to survival has been the ability to rally group members to

give freely and enthusiastically of their blood and treasure in wartime. The only effective way to do this has been to portray the unit and its territory as belonging to the residents of the territory, in some collective sense (however vaguely defined). Thus the residents are being asked to fight not for somebody else's turf (for which service they would be inclined to demand high wages), but for their own, their native soil. Therefore, the administrators must hold themselves out as merely trustees or fiduciaries, wielding power on behalf of the residents. Even the absolute monarchs of old based their claims on "Divine Right," the notion that God had anointed them to be the stewards of the people's interest. This same concept of stewardship extends to the directors and officers of a widely-held corporation.

The problem with such arrangements is that they give the administrators incentives to manage the unit for ends other than the long-term survival interest of the unit. For example, there is an incentive for the leaders to mortgage the future in order to buy the favor of the members in the short term. If they don't, some rival out-of-power clique can push them aside by assembling a winning coalition with promises to do this. The future generations that stand to lose in this process are not around to look out for their interests.

Another problem is this whole area of coalition politics. To stay in power, the incumbents have an incentive to put together a constellation of interests that reflects only a portion of the group as a whole, and use the powers of their office to benefit the leaders and their supporters at the expense of other elements in the group.

Note that these problems apply to essentially any political context, regardless of how possession of the mantle of leadership is determined. In the United States, the maneuvers are done in the context of liberal democracy, where elections are central, as different blocks of voters are courted by contenders for power. In the U.S.S.R., the maneuvering is

among bureaucratic factions: the party, the army, the secret police, etc. For more on the unwritten rules under which these sorts of maneuverings take place, see my article, "The Three Pillars of the State" in issue #99 of *The Connection* (see Bibliography).

In a proprietary community, ownership is vested in a single proprietor, or in a small group (such as a family, or a business partnership). All other people (the residents of a residential community, the employees of a factory, etc.) are present on the basis of bilateral contracts with the proprietor. These are generally short-term agreements, with either party free to let the relationship end, or renew it by mutual consent. Thus the proprietor, and he alone, stands to lose by any unwise policy, or gain by a wise one. Presuming that he wishes to pass ownership on to his descendants, his incentives will be to operate for the long-term viability of the operation. And since none of the other residents, employees, etc., has any equity in the community, there is no incentive to try to play one subgroup off against another.

Of course, since such a cold, businesslike relationship isn't likely to inspire the tenants, employees, etc., to fight and die for the community, nor contribute freely to its defense, such operations stand to do poorly in the agricultural era. But in a world of cheap weapons of mass destruction, the availability of willing cannon fodder is no longer a major advantage in warfare. If communities have a quarrel that comes to blows, some limited fencing might be engaged in using mercenaries. But if one side seemed to be losing, he could threaten to take the winner down with him in a mass-destruction holocaust if the winner tried to press his advantage. Large quantities of cannon fodder would avail the dominant power little in the face of such a threat.

Should trouble seem to be brewing, quite likely the residents of all communities involved would decamp for other parts for

the duration. In fact, this response has been the typical choice of the Jews of the diaspora (at least, those that have survived), and most of the ones that have survived to the present have been the ones whose ancestors were the quickest to move out. For example, the Jewish community in the capital of El Salvador evaporated almost overnight when the recent trouble started there. Naturally, this attitude has contributed to the low esteem of the Jews in the eyes of "right-thinking patriots" in their countries of residence, but it has served its practitioners well. And it bids fair to become the prevailing attitude of a world of cheap weapons of mass destruction.

For the above reasons, one should look for substantial interest in the proprietary-community form of organization in the future world of cheap weapons of mass destruction.

It might seem that this scenario would require a reversion to small-scale or cottage industries, forfeiting the advantages of division of labor. But this problem is not insoluble.

A solution is to have people stay where they live, and work by remote control. Even today, many white collar workers could do their jobs with a telephone and computer terminal (containing a typewriter and TV screen). The main impediment to this is institutional inertia. In the face of necessity, the means would be available. But what of people who work with their hands? Here, ironically, the nuclear industry has supplied the answer. There are devices called remote manipulators, popularly known as "Waldoes", after the science fiction story of that name by Robert A. Heinlein which first proposed them. A worker slips his hand into a device which then detects every motion of his hand and fingers. These signals are sent over a telephone line, and a mechanical hand somewhere else moves exactly as the worker's hand did. If the mechanical hand meets resistance from an object, a signal is sent back to the detecting device, and the worker meets with the same amount of resistance from the device. A TV camera enables him to see

what he is doing. These devices were originally used to handle plutonium, so that the worker didn't have to risk getting poisoned.

With these Waldoes and computer terminals and telephones, the worker can stay at home. To go to work, he dials the phone number of his workplace, and hooks up. If work is slack at one place, he just dials another number and hooks up to another factory. In this way, labor can flow to the most efficient use as dictated by the laws of supply and demand -- without the human disruption so often used as an argument against laissez-faire capitalism. Not only does the worker now feel less emotionally involved with what goes on at the plant, and thus less likely to have a motive for violence, but the fact that he never physically enters the plant removes the opportunity to smuggle weapons in. Removing the workers from the factory also reduces problems of heating and cooling the plant, controlling noise and poisonous substances, making machines safe, and so on.

Nevertheless, it would remain necessary to ship material around the world -- not to mention the fact that people might like to travel for pleasure. One means of doing this is vacuum tube trains. A tunnel is dug at a steep angle down to a depth of several miles, and then levels off. At the other end of the line, the tunnel rises at a steep angle again. Rails are laid in the tunnel, and the air is pumped out. A train can now be allowed to freely roll down the steep slope, building up to many times the speed of sound before leveling off. At the other end, it slows down again automatically as it ascends the slope. The only energy required from outside is enough to overcome residual friction. Such tunnels would be relatively difficult to sabotage (though of course it could be done) and would not involve the communities under which they passed (cutting negotiating costs).

CHAPTER SEVEN
RESOLVING DISPUTES

One of the most obvious problems in a society with a large number of independent units is how to resolve disputes efficiently. Disputes within a community would be handled in accordance with the procedures in the agreement with the owner, and enforced by the owner. But what of disputes between communities? I expect such disputes to be handled in much the same way that disputes between nuclear powers are handled today. First and foremost, there is the overriding fact that war involving weapons of mass destruction is always present as the court of last resort. As with the superpowers today, this fact will cast its shadow over every dealing between the communities. As a result, a wide range of arbitration and other procedures will evolve, and the vast majority of disputes will be settled within that framework. But what happens when those procedures fail, as they are bound to in at least some cases, sooner or later? Is the only alternative a war that will likely destroy both communities? In some cases, probably yes -- cases of desperation by one of the communities. But it has occured to me that in many of the cases that can't be settled by negotiation, there is another conceivable option -- the duel.

I want to make it clear that I'm not talking about the decadent form of dueling of the Renaissance and later, as depicted in works like THE THREE MUSKETEERS, where the young bloods with nothing better to do go around challenging each other. This sort of thing became a serious problem in Europe (especially France), where there was actually getting to be a shortage of heirs to titles because of the carnage. I'm talking about the original concept of the Code Duello as it was created in the early Middle Ages to settle disputes between what Mario Puzo's Godfather would have called "serious men; men of respect," without going to outright warfare.

With those ground rules established, let's look at the relevant similarities between such a future and the early Middle Ages.

First of all, there is the fact that the leaders of these units cannot compel people to join them, but must make them an attractive proposition. A leader who makes a policy of settling disputes by duels is less likely to wind up plunging the whole area into war all the time. In the normal agricultural society, of course, the peasants are conscripted to fight the wars, and don't have much chance to vote against a leader with their feet. With smaller units, there aren't the cultural, linguistic and physical barriers to emigration that there are with large nations. It is not hard to pack up and move down the road. The economics of a Berlin-wall strategy are controlled by the cost of guarding the borders (proportional to the perimeter of the unit) and the number of people being guarded (proportional to the area of the unit). In a small unit, you approach the economics of running a maximum security prison -- which is now around $15,000 per inmate per year. It is hard to get $15,000 out of a slave laborer in a year to make it pay off.

A second factor favoring dueling is the question of surviving war. The smaller the units the more likely it is that even the winner (and most people getting into a war expect to be the winner; otherwise, they wouldn't bother to fight) will suffer significantly. With larger units, armies can be sent off to the front to bear the brunt of the fighting. Add in thermonuclear weapons, and this factor becomes overwhelming. In a thermonuclear war, the likely result is everyone getting obliterated (however, this does not invalidate the game-theoretic conclusion that avoiding war at all costs is not always the best policy).

A third consideration is efficacy. If the President of the U.S. were killed in a duel with another head of state, this wouldn't really affect the country much. The VP would be sworn in, and things would go on pretty much as before. But with a unit of about 200 people (the size of a very large hunting or gathering band), the loss of the head person would be equivalent to a

nation of 200 million losing the top million people -- President, VP, Congress, state governors and lieutenant governors and legislators, judges, the officers and boards of the Fortune 500 companies, labor leaders, and so on. The country would really be decapitated. And with the greater mobility between units that is the basis of this whole projected setup, those left behind would be much less likely than now to feel a duty to take up their fallen leader's banner. Compare it with the situation in which one company takes over another after a bitter proxy fight. Most of the employees couldn't care less. The top management will be replaced, but most people will go right on working for the new bosses. Those that aren't happy with the new regime will seek employment elsewhere. Thus a duel on the terms that the winning side gets its way would be likely to settle the matter; those left behind on the losing side wouldn't feel any great commitment in the matter under dispute, and could live with the decision without great loss of face. I could well see it happening, though, that a duel might involve more than one person from each side, to include all people on each side with strong feelings in the matter at hand. More about this later.

Having discussed why duelling might become accepted, let's move on to the rules under which such duelling would likely be conducted. A basic consideration (in the past or the future) is that the outcome of the duel should have the same expected chance of victory for each side as war, if war were resorted to. Otherwise, the party that stands to be at a greater disadvantage (or at less of an advantage) in the duel than in a war will tend (all other things being equal) to be motivated to opt for war. In the Middle Ages, the essential element of war was combat between armored mounted knights. Therefore, the duel consisted of such combat. If a knight or group of knights from one side were defeated by a corresponding force from another in a duel, the chances were that the same side would have won the war. In the future, one side's ability to make war will depend on having the financial, administrative, technical,

etc., resources to mount a mass-destruction attack.

Once a side has a certain minimal level of such resources, things tend to be relatively equal on the hardware level. Mass-destruction weapons tend to be the greatest equalizers since Samuel Colt. Thus the first step will have to be establishing that one has the "standing" to issue a challenge to a duel. This was relatively unimportant in the early Middle Ages: if a peasant wanted to challenge a lord, there was no reason for a lord to hesitate. A mounted, armored knight with a lifetime of training could make quick work of an untrained, ill-equipped peasant, if the peasant really wanted to commit suicide in that fashion. In the Renaissance and later, determining whether an individual had "honor," and was thus entitled to the considerations of the Code Duello, was more of a problem. More about how this problem might be handled in the future later.

Among those with standing, then, how might the duel itself be conducted? Traditional hand-to-hand combat would have little relevance in a world of cheap weapons of mass destruction, so the traditional swords, pistols, etc., seem hardly relevant. In an actual, no-holds-barred showdown between communities, the key factor would be the ability to correctly assess one's opponent's intentions, and the ability to induce that opponent to make the assessment of oneself that one wished him to make. These are essentially the skills of the poker player: to tell from an opponent's demeanor just how good the cards he holds are, and exactly how far he is prepared to go in backing his position before folding; and to manipulate one's opponent's assessment of the nature of one's own cards and willingness to back them.

Of course, besides poker itself there are many forms of contest that are essentially analagous games of strategy, judgment and bluff, and any one of them would serve equally well. The choice of the specific game might well be left to the challenged party (analagous to the choice of weapons in the traditional duel) to further discourage excessive challenges.

How might such poker-duels be expected to come out? For the most part, the parties finding themselves faced with deulling situations will be seasoned professionals at that sort of thing. There will be few ribbon clerks at the table. Therefore, the best analogy might be with the World Series of Poker held annually in Las Vegas. In this contest, a selected field of top poker players start with equal stakes, and play until one has all of the money. Most of the year, these players make their living by playing against inferior opponents. In these games, their skill is decisive. However, once a poker player reaches a certain skill level, all are on an essentially equal footing. All of them know the relative probabilities of the different hands, the chances of improving a hand with a subsequent card, etc. And all can keep their faces blank, so that even the most shrewd observer cannot glean any information about their holdings or intentions. In the World Series of Poker, the play generally proceeds on a very conservative basis. On each hand, each player figuratively rolls a set of mental dice. On a certain small percentage of all hands, a player suddenly makes a huge bet without warning. Does he really have a strong hand, or is he bluffing? If raised, will he raise the stakes in turn, or fold? There is no way even the most skilled player can really tell. Therefore, his opponents must roll their own mental dice to decide whether to fold themselves, or challenge. On the luck of a series of these challenges, the World Series of Poker is decided. Thus a given side's chance of winning such a contest is roughly 50% (assuming that both sides are, indeed, composed of "serious men; men of respect," and that there are no amateurs who are in over their heads).

Then there is the question of what the stakes should be. If the winner merely gets his way in the matter originally under dispute, and the loser must yield, this creates an incentive to provoke confrontations. Instead, the loser of a duel should suffer substantially more of a loss than if he had merely yielded

on the original point. However, the winner should not stand to gain much more than the original point, lest those in moderately pressed straits be tempted to risk all on one roll of the (mental) dice to gain much (those in sufficiently dire straits will, of course, have no alternative to challenging someone). The obvious resolution to this is for the losing side to die. To implement this, the contests would have to be conducted under the control of a disinterested party, likely a reputable firm specializing in such matters and agreed to by both sides. If desired, scorekeepers could be automatic, with the players seated in electric chairs to administer a lethal current as soon as the last hand or round is lost. Each side would no doubt want its seconds to examine the arrangements carefully in advance to be sure everything was in proper order.

This still leaves the question of when there will be duels, and who will participate. If people are too quick to issue challenges, their odds of surviving a series of duels will be small, and their chances of eventually winding up in a war will be great. In addition, they will tend to acquire reputations as troublemakers, and will tend to have difficulty getting people to do business with them, for fear of being drawn into their imbroglios. On the other hand, if people are too slow to challenge others, they may acquire reputations as pushovers, and others will make more and more demands of them. Their positions will either be nibbled away, or they will have to fight a series of duels to recover their reputations and discourage people from making undue demands. Quite likely, many challenges will be settled "out of court;" that is, the dispute will be resolved before the duel takes place.

Similar considerations govern the number of people from each side who will participate. If one side demands too few people from the other side participate, then even if they win there may be people in key positions on the other side who

have considerable stake in the matter under dispute. They may decide that they would lose too much face by acquiescing in the result of the duel; that is, they would get too much of a reputation as pushovers. Thus they may feel impelled to issue a new challenge to the victors in the original duel, facing those victors with double jeopardy. Thus the original disputants will want to be sure that enough people from the other side are called out.

However, if too many peripheral people are called out, the undue wrath of their friends, relatives and business associates, etc., is risked. This could lead to follow-on challenges and the multiple-jeopardy problem. Therefore, the correct balance in the scope of challenges would have to be struck. Each side would no doubt have seconds who would conduct appropriate negotiations to determine the details of the actual duel.

This leaves the question of who has standing to issue a challenge, and whose challenges may be ignored without undue consequences. This is not likely to be settled on the basis of some highly abstract principle of law or some such, but on the down-to-earth question of the consequences of ignoring a challenge. As I said above, war is the court of last resort. If a challenge is refused, the challenger must either back off (with great loss of face, inviting everyone to make their own demands on him) or launch a war (with a great risk of mutual destruction). Thus, having standing will mean having the ability to launch a war. If a challenger cannot launch a war, then challenges can be treated with impunity. So how can ability to launch a war be shown?

Rather than maintain their own nuclear forces, it may be cheaper for people to hire mercenary operators as needed. All other things equal, the larger outfits will have lower costs. But if a nuclear force is too big (has too many clients), there is too great a chance that the people one wants to attack will also be clients of the same firm, and may choose the wrong side in the

crunch. Thus, people will patronize mercenaries that are small enough to really need one's business, and to be fairly reliable when push comes to shove. To achieve deterrence, one will want it known that one has a standing arrangement with such a force to avenge one's destruction in a surprise attack. Thus one will put down a deposit to cover the cost of such revenge, or will arrange a letter of credit to be paid in such a case, or the like. The mercenary force will then announce and certify to all and sundry that such an arrangement is in force. However, one may not want to publicize the exact level of retaliation paid for (a single strike against one attacker? a general campaign against anyone associated with an attacker?) to keep potential enemies guessing. Having such a deposit in place will serve as the credential entitling one to have one's challenges given some weight.

In order for the credentialing process to be credible, it will be necessary for the mercenary firms to be well-known, reputable entities. To keep these firms from going underground, where it will be hard to tell who's who, and who can be trusted in a pinch, and who is whose client (to avoid conflicts of interest), it will have to be accepted that a mercenary force acting on behalf of a client is not to be held responsible for the destruction, and is not to be made the object of retaliation itself. That is, it will be recognized that these are soldiers merely obeying orders and (Nuremburg notwithstanding) trying to "punish" them will just make the would-be "punishers" more enemies, and thus would be counter-productive. The non-responsibility convention will exempt the would-be "punisher" from loss of face in not attacking the mercenaries' home base. Of course, the mercenaries would have to be ready to fight on their own behalf like everyone else -- in fact, given their business, probably more often than most.

CHAPTER EIGHT
THE FAR FUTURE

But where is this whole process of dispersion leading? To explore one possibility, consider the ongoing process of transferring human function to inanimate devices. The substitution of mechanical power for human muscle power is easily understood. But a similar transfer of mental function has been going on for longer than you might realize. It started about 5,000 years ago, when people started transferring their memories from their heads onto paper and stone -- writing. This early form of bionic brain didn't forget things, or remember them wrong. Furthermore, they could be sent over long distances, and "attached" to other people's brains. As time went on, these prostheses became more elaborate. Printing was invented, then electronic media, then computers. Many people use computers to perform functions, like memory and calculation, that were formerly done by organic mental processes, "linking" the computer to the brain via the "channels" of hand and eye. Even more intimate and direct links are being developed all the time (computers that speak English, that can directly sense the position of the hand or body by devices attached to them, etc.). Eventually, computers will be able to bypass the sensory-motor apparatus altogether. Machinery actuated by "thoughts" directly (i.e., by brain waves) has been demonstrated (in fact, the "alpha wave machines" being widely sold commercially are such devices). In the other direction (computer to man), deaf people with completely dysfunctional ears have been able to "hear" the output of small broadcast-band radio transmitters implanted in the skull directly (apparently something in the neural structure of the brain acts as a receiver). As this sort of thing progresses, more and more brain function will be transferred to the computer, since it isn't subject to the speed, size or aging limitations of the human brain and skull. At some point, it will

no longer be possible to localize the phenomena of "mind" and "ego" in the organic brain alone. Even within the organic brain today, it is not possible to localize consciousness. Except for certain parts of the brain that perform utility functions (motor control, etc.) any given part of the brain can be destroyed, and the rest takes over for it. People have even had a majority of their brain destroyed with no significant effect on their personality.

Eventually, everything will have been transferred to the computer, and the body will be operated as, for example, computers run numerically-controlled machinery. The body may be replaced by an artificial apparatus, or new, young bodies of conventional organic makeup may be grown instead to replace aging ones. People might have a variety of bodies to suit their moods or the needs of the activity at hand. Bodies might be kept in various places so you could "travel" simply by switching control from one body to the other. Or you could get in touch with Hertz rent-a-body. For long distances, where the transmission lag between body and computer was annoying, the entire contents of the machine could be transmitted to a computer at the destination -- in effect, "teleportation" (the telephone is a primitive form of "remote body"; vision has already been added on an experimental basis; next would come Waldo arms and mobility of the unit, which would involve no breakthroughs from present technology; and so on). Such transportation would appear instantaneous to the teleportee -- activity in the computer would be halted, each memory location would be scanned and transmitted, then the receiving computer would be turned on. Such "freezes" and restarts would also be a form of "time travel" (albeit one way -- more like suspended animation): if you were bored with current conditions, you could just "switch off" for a year (or a millenium), while your computer was somewhere safe, like interstellar space.

Of course, there may be no need of bodies at all. Each computer can instead generate a pattern of neural impulses that causes others it's in contact with to subjectively perceive a body when they receive them (just as television signals cause a pattern of light on a screen which in turn creates a subjective sensation of seeing the original scene (or, in the case of animation, a scene that never existed except in the imagination of the artist) -- only covering all the senses and with much greater resolution). The same extends to other physical objects: why build a fancy house, when the computer can generate a patttern of impulses that will give the subjective sensation of being in whatever house/mansion/castle/grass shack strikes your fancy at the moment? Or of eating any food you decide to sample? Just as art has moved from strict representation into abstract forms, there is no reason the stimulation patterns have to attempt to mimic the external world. The way is opened for exploration of entirely new forms of experience (if that word still applies).

One problem is that of boredom. Today, with everyone across the world reading the same news, seeing the same movies and TV shows, listening to the same music, etc., there is a homogenization of culture: a lack of variety that could get critical as virtually instantaneous communication becomes more comprehensive. Some have suggested that as long as there are more people around than one can meet in a lifetime, this is no problem. But that is only true if the ideas, attitudes, opinions, etc., of everyone are of equal merit. In the first place, the homogenization problem crops up; secondly, a relatively small percentage of the world's population creates most of the art, music, literature, movies, TV shows, conversation (via magazine interviews, radio and TV talk shows, etc.) that occupy most of the people. You could meet people at random all your life and never meet more than a tiny fraction of these creative people, yet you would be much poorer in stimulation for the lack. This is because of the "chain reaction" effect -- if

those in direct contact with a person think that his art, music, jokes, philosophy, etc., have merit, they will tell several other people, and so on until it gets to almost everybody (or at least to someone in mass communications who disseminates it worldwide). Naturally, virtual immortality would exacerbate the problem. The only factor that could maintain the separation needed to provide different people with a different cultural background is distances large compared to light-weeks (at least). Consciousnesses would be spread out through space, travelling singly or in groups (either the computers travelling physically or the information transmitted to computers elsewhere) at a level of intercourse that would permit savoring the novelty of different groups' ideas without obliterating them.

That might even be why we haven't seen any other intelligent races in the Universe. To maximize novelty, it may be policy to let a new species develop as long as possible without swamping it with the accumulated mass of galactic culture, communicating with it only after it has expanded into space and that culture can no longer be hidden (a vastly superior technology doesn't necessarily mean the ability to hide from a less developed culture -- if Polynesians from an undiscovered island landed on the beach at Santa Monica, the culture that built Los Angeles couldn't hide it from them).

This concludes our look at the future world of cheap weapons of mass destruction. Many of these ideas were developed in exchanges with other participants in *The Connection* (see Bibliography). The arguments presented here are necessarily sketchy, to cover as much ground as possible. More detailed support can be found in back issues of *The Connection.* Best of all, if you're interested in these sorts of things, join *The Connection* and put your questions directly to me. I look forward to many fruitful exchanges.

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Analog Science Fact and Science Fiction magazine, *Davis Publications, 380 Lexington Ave., New York, NY 10017.* The April 1979 issue contains an article by George Harper emphasizing the difficulties confronting the nuclear weapons builder. In spite of this, figures are given for laser separation of U235 from U238 that are quite encouraging to such builders.

THE ART OF COMMUNITY, by Spencer MacCallum. This is the basic book on proprietary communities. It emphasizes the economic efficiency gained when the owner of land also has the power of government there. This avoids the divergence of interest that exists when there is private ownership and political government vying for control of the same land. The (transitory) political government has the incentive to milk as much in the way of taxes and other extractions of value from land under its jurisdiction while the incumbents remain in office, regardless of the long-term consequences. Available from Loompanics (below) for $4.95.

BLASTERS' HANDBOOK, *DuPont Chemical Company, and* **THE CHEMISTRY OF POWDER AND EXPLOSIVES, by Tenney L. Davis,** *Angriff Press.* These books cover high explosive technology which can be used to make nuclear weapons. Many other books describing how to make explosives at home are available from Loompanics Unlimited (below).

The Connection, *c/o Erwin S. Strauss, 9850 Fairfax Sq. #232W, Fairfax, VA 22031.* Formerly titled *Libertarian Connection,* this is the 14-year-old open-forum publication referred to in the text. Subscriptions are $10 for one year (8 issues), $1 for a sample issue of my choice, and $1.50 each for specific back issues (outside North America, $16 or 54

International Reply Coupons (IRC's) per year, and $2 or 7 IRC's for back or sample issues, all sent air mail). Each subscriber may (but needn't) contribute up to three 8½ inch by 11 inch pages per issue to be printed half-size at no extra charge. Each issue consists of the contributions so received, printed unedited. Many of the lines of thought in this book were developed through this medium, which contains more detailed supporting arguments. Back issues containing articles mentioned in the text are #99 ("The Three Pillars of the State") and #108 ("The General Theory of History"). I look forward to an ongoing discussion of the issues raised here in the pages of *The Connection.*

THE CURVE OF BINDING ENERGY, by John McPhee, *Ballantine Books.* This book created concern over the safeguarding of fissionable materials in the nuclear power industry and the nuclear weapons establishment. It contains details of uranium and plutonium chemistry, and mentions many other books with technical information.

THE EFFECTS OF NUCLEAR WEAPONS, compiled and edited by Samuel Glasstone and Philip J. Dolan, *prepared and published by the U.S. Departments of Defense and Energy, 1977.* This 653 page book covers the subject extensively. This information would be useful for planning survival in the event of a nuclear incident.

Encyclopedia Britannica. This handy source, available at virtually any library, contains much useful information about various aspects of nuclear weapons. The techniques for concentrating uranium ore are discussed in particular detail, with diagrams. Most investigators studying the subject of clandestine nuclear weapons agree that this is the logical starting point for the aspiring bomb maker.

HOW TO START YOUR OWN COUNTRY, by Erwin S. Strauss. The problems faced by people trying to start their own countries, as described in this book, are similar to those that will face the organizers of the independent communities of the future. This is especially true with regard to matters of internal organization. The advent of cheap weapons of mass destruction places the alternative of full sovereignty within the realm of possibility. $7.95 from Loompanics Unlimited (below).

L-5 Society, *1620 N. Park, Tucson, AZ 85719.* This is a group dedicated to promoting the colonization of space — the building of human habitations dispersed throughout the volume of space itself, not on any planet. A society of such habitations would be highly resistant to nuclear threats. Individual units might be attacked, but the society as a whole would survive. They sell many publications describing the technology involved.

Loompanics Unlimited, *PO Box 1197, Port Townsend, WA 98368.* The publisher of this book, this company sells a variety of books of interest to readers of the present volume. Their catalog contains many books about building a retreat before a disaster and making other preparations, and about survival after such an event. There is material specifically concerning surviving nuclear bombs. Many of the books mentioned in this Bibliography are also available from them. The catalog costs $2.00.

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shows more detailed drawings of the operations of those weapons, and text that emphasizes the political aspects of the H-bomb program in the United States.

THE SELFISH GENE, by Richard Dawkins, *Oxford University Press, 1976.* This book analyzes evolution in terms of game theory — choosing courses of action on the basis of possible rewards and penalties and the probability of incurring them. Dawkins talks mainly about biological evolution, but the same concepts apply to social, cultural and political evolution as well. These principles will govern which communities and people survive in the future, and which do not. It recognizes such restraints on behavior as loyalty and morality as means evolved to serve an end, and helps the reader step outside them to analyze evolutionary processes from an objective point of view. This will be a very useful technique in planning one's actions in the future world of widespread weapons of mass destruction.

SUPERVIOLENCE: THE CIVIL THREAT OF MASS DESTRUCTION WEAPONS, *(NTIS Report AD-896 623/6 GA), National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161. 1972, 446 pp, $4.50 in microfiche.* This is a government-sponsored survey of the public literature on nuclear, chemical, biological and radiological weapons. By this time, its information on nuclear weapons has been made obsolete by the disclosures recounted in the present book, but the portions on the other weapons provide quite detailed how-to-do-it instructions. An extensive bibliography is included to assist in tracking down all the technical details necessary to mount a successful mass-destruction weapon program.

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ABOUT THE AUTHOR

Erwin S. Strauss was born in 1943 in Washington, DC, and grew up along Embassy Row. He lived in Europe and Asia with his father, a consul in the diplomatic service of the United States who served as First Secretary in the American missions in Paris and Bangkok. Mr. Strauss received a Bachelor of Science degree in Physics from the Massachusetts Institute of Technology. After graduation, he worked in the areas of electronic warfare and the analysis of nuclear weapons effects. He is currently active in the consulting field, and as a freelance writer.

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